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VOLUME SIX NUMBER FOUR

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Combustion is published monthly by Combustion Publishing Company, Inc., a subsidiary of Combustion Engineering Company, Inc., 200 Madison Avenue, New York. Frederic A. Schaff, President; Charles McDonough, Vice-President; H. H. Berry, Treasurer; G. W. Grove, Secretary. Subscriptions, including postage, United States, $2.00, Great Britain, $2.50 a year. Canada, $3.00 (includes Canadian Tax). Other countries, $3.00. Single copies: 25 cents. Copyright, 1934, by Combustion Publishing Company, Inc. Printed in U.S.A. Publication office, 200 Madison Avenue, New York.

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EDITORIAL

Calvin W. Rice

The sudden death of Calvin W. Rice, Secretary of the American Society of Mechanical Engineers, on October second, removes from engineering circles one of its most widely known personalities.

An electrical engineer by training and early business association with such companies as the Thomson-Houston Electric Company, the Kings County Electric Light and Power Company, New York Edison Company and the General Electric Company, Doctor Rice turned to the mechanical engineering field in 1906 when he became Secretary of the A.S.M.E. A very considerable part of the credit for the growth, broadened activities and increasing prestige of the Society during the past twenty-eight years is due to his vision and ceaseless efforts. He was keenly interested in research, in raising the prestige of the engineer in civic affairs and in bringing about closer relations between engineers internationally. His acquaintance and close contacts with engineers and engineering societies throughout the world were undoubtedly greater than those of any other man. His role might have fittingly been termed that of an "engineering ambassador."

Active until within a few hours of his death by cerebral hemorrhage, the end came as he would have wished—in the midst of the work to which the mature years of his life had been dedicated.

Another Yardstick

The *New York Herald-Tribune* of October first states that the President recently sent a telegram to Mayor Hoan of Milwaukee in which he said:

"I am strongly for the Great Lakes—St. Lawrence Seaway which, in addition to providing the United States with a great international highway for shipping will give us a fourth yardstick in the power development projects already started by the Government on the Colorado and Columbia Rivers and in the Tennessee Valley."

Coincident with this the trustees of the New York Power Authority have lately made a personal inspection of the T.V.A. projects and Chairman Frank P. Walsh has given out a statement in which he predicted that the St. Lawrence Development would save consumers of New York State over sixty-four million dollars annually in reduced electric rates.

The St. Lawrence project has been hanging fire for a number of years. Engineering surveys and plans have been completed although no final decision has been made as between a single stage or a two-stage development. The Treaty has been negotiated and signed, but its ratification by Senate and by the Canadian Parliament yet remains. It is anticipated that the administration will make strenuous efforts to secure ratification by the next Congress. Whether Canada will ratify promptly is uncertain in view of its already vast hydro developments in that region and the expense involved. But assuming that it does ratify, some years must elapse before St. Lawrence power from this development will become an actuality in New York State.

Nevertheless, the situation creates an uncertainty in long-time planning by utilities in New York State. Unlike the Colorado and Columbia River projects, there is little question of markets to absorb St. Lawrence power, but the methods of its disposal and the areas affected involve questions that are likely to affect utility investments.

Power Activity in Great Britain

From all accounts the central station industry in Great Britain is going through an expansion period similar to that obtaining in this country a few years back. Extensions to a number of large stations have been made this year and two new stations, at Swansea and at Fullam, are nearing completion. Moreover, the Central Electricity Board has announced plans for further immediate extensions that will add half a million kilowatts capacity at an equivalent expenditure of over twenty-five million dollars. As further evidence of this activity one of the large power equipment manufacturers recently announced that its sales had increased 120 per cent over last year.

One must infer from this that England is entering a period of industrial activity. Completion of the Grid system, linking practically all the important operating properties in England, Wales and Scotland and making electricity available to 98 per cent of the population, is undoubtedly a factor. There are also signs that the British public is becoming more electrically minded, although probably not to the same extent as obtains in this country, for the capita yearly use of electricity there is only 224 kilowatt-hours as compared with over 500 in the United States, this despite a greater density of population in Great Britain.

The new stations and extensions show a trend toward larger boilers and turbines, although not as large as are found in many stations in this country. British engineering opinion apparently still favors having several boilers per turbine as contrasted with the trend toward a single boiler per turbine in the United States. Steam pressures around 800 pounds, with reheating, and the use of both stokers and pulverized coal in the same station are noted among several of the British installations.

Analyses of Coals of the United States

By P. B. PLACE

Combustion Engineering Company, Inc.

Moisture and ash-free analyses of coals are usually similar for coals mined within limited areas. A list of average moisture and ash-free analyses has been prepared using state counties as selected limited areas. The list is useful for checking doubtful analyses or for setting up a complete analysis for a coal when only the source, moisture and ash are known. Further articles will be prepared covering in greater detail the coals of the principal coal producing states.

THE raw material and geological influences involved in the formation of coal beds combine to make coal a most complex substance chemically. The variety of vegetable matter intermittently laid down over long periods of time and the different degrees of processing by heat and pressure to which these beds have been subjected have resulted in a variety of coals in different parts of the country and at times even in the same state and county.

A great deal of work has been done in successfully developing various classifications of these coals. They range from simple descriptive terms such as "coking," "hard," "high volatile," "free burning," etc. to elaborate and carefully prepared outlines such as has been recently developed by the American Society for Testing Materials. The trade often uses trade names of seams, districts, counties or states to classify their products. Examples are "Big Vein," "Pocohontas," "Hocking Valley," "Franklin County" and "Iowa Coal."

All of these classifications and identifications convey definite information to those familiar with the nomenclature and are essential working tools of the trade and geologists. None of them, however, indicates the analysis of a coal to the uninitiated and to the salesman, contractor, test engineer or operator who often requires a complete ultimate analysis for his calculations and has to accept a submitted analysis, collect a sample of the coal and have it analyzed, or select from lists of analyses of typical coals one that appears to fit the coal in question. Often there is an element of doubt as to the reliability or applicability of such analyses.

Most coal analyses are reported on an "as-received" basis and the analyses in a selected list of typical coals on an "as-received" basis present a confusing variety of analytical values that are of little practical use. Often several analyses of the same coal will show no uniformity in the respective analytical values and cultivate a feeling of doubt as to their accuracy.

The three following proximate analyses of a Sullivan County, Ind., coal were taken from a Bureau of Mines bulletin and illustrate the variations in the "as-received" analyses of a coal from the same source.

	"As-received" analyses Sullivan Co., Ind. coal		
	1	2	3
Moisture	9.4	12.6	13.3
Ash	3.3	6.9	12.9
Volatile matter	38.5	36.0	32.7
Fixed carbon	48.8	44.5	41.1
Btu per lb	12,600	11,790	10,540

Most of the variation in the analytical values on an "as-received" basis for coals from the same mine or mining area is due to the variable amounts of moisture and ash mixed with the coal substance. Freshly mined coal containing 10 per cent moisture and 10 per cent ash and that analyzes 72 per cent total carbon will contain 81 per cent carbon if the coal is cleaned to 5 per cent ash and dried to 5 per cent moisture before use. Since every other item in the analysis changes in a similar manner, the variety of analytical values for this same coal is evident.

Moisture and Ash-Free Basis Desirable

The moisture and ash in a coal are largely extraneous and serve more or less as diluents of the true coal substance. If the coal analyses are calculated to a moisture and ash-free basis it is generally true that the composition of the coal substance itself is fairly constant for coals mined within a limited area.

The following moisture and ash-free values for the Sullivan County coals given above are examples of the effect of conversion to this basis.

	Moisture and ash-free analyses Sullivan Co., Ind. coal			
	1	2	3	Average
Volatile matter	44.1	44.7	44.3	44.3
Fixed carbon	55.9	55.3	55.7	55.7
Btu per lb	14,450	14,650	14,300	14,470

An average of many such analyses will give a basic analysis of the coal substance from that area that can be safely used in the absence of more reliable data. Knowing the moisture and ash and the source of the coal, its complete analysis on any basis can be set up from a table of reliable moisture and ash-free analyses. The moisture and ash can generally be estimated for calcu-

lation purposes or readily determined from samples in any small chemical laboratory but a complete analysis can only be determined accurately by an experienced coal chemist in a well equipped laboratory. Such an analysis is, of course, not equal to a direct analysis of a representative sample by a competent coal chemist but in the absence of specific data the averages are useful and serve as checks on the results of a poor sampling or poor analysis.

The U. S. Bureau of Mines Analyses are Widely Used

The Bureau of Mines has made thousands of complete analyses of coals from all of the coal-bearing states and is probably the most reliable authority in this country on fuel analysis. These analyses are available to the public in many government publications and have been freely used in preparing the averages given in this article.

For convenience the counties of the states have been used as the limited areas in the survey but an understanding of how coal beds are formed is necessary to a judicial use of the averages as county boundaries are not always ideal for classification purposes.

Briefly, coal beds are relatively thin and more or less parallel strata of partially carbonized vegetable matter laid down at widely different periods of time. In any vertical cross-section of a coal-bearing area there are normally several of these coal strata or seams varying from a few inches to several feet in thickness and separated from each other by from twenty to a hundred feet of sedimentary rock formations. Any one coal seam has been formed from a mascerated accumulation of decayed vegetation which has been highly compressed and partially carbonized by geological influences over a long period of time.

It is reasonable to expect that the composition of this coal substance should be similar within limited areas provided that the area has been subjected to similar degrees of processing by pressure and heat. If the selected area is such that it includes parts of two or more separate deposits or if any one seam has been subjected to different degrees of processing within the limited area, then two or more coals of different composition and characteristics may be mined from this seam and area. Fortunately this is unusual and in many cases the coal substance from several counties is sufficiently similar in composition to justify combining the averages for several counties into a single average for the combined areas.

Only Important Seams Considered in Preparing the Tables

Of the several coal beds in the vertical cross-section of any county or selected area, only two or three are generally of commercial value and often only one is mined extensively. In preparing the tables given herein, only the most important seams of a county have been considered. No attempt has been made to identify the different seams where more than one distinct grade is given for the same county. Identification can

TABLE 1. Variation in Average Analyses of the Pittsburgh Seam in Different Areas. (Moisture and Ash Free Values.)

County	State	V. M.	S	H	C	N	O	B.t.u/lb
Allegheny	Penna.	38.4	1.3	5.5	84.2	1.6	7.4	15090
Fayette	Penna.	36.6	1.6	5.5	85.2	1.8	5.9	15275
Greene	Penna.	39.0	2.1	5.5	84.7	1.7	6.0	15160
Westmoreland	Penna.	37.3	1.5	5.5	84.6	1.7	6.7	15130
Athens	Ohio	42.8	4.5	5.2	79.2	1.1	10.0	14280
Belmont	Ohio	43.2	4.7	5.4	80.5	1.3	8.1	14710
Guernsey	Ohio	47.4	5.6	5.6	79.8	1.5	7.5	14630
Jefferson	Ohio	41.3	3.1	5.5	81.6	1.5	8.3	14790
Alleghany	Md.	18.8	1.1	4.8	89.2	2.0	2.9	15660
Harrison	W. Va.	43.3	3.5	5.4	83.4	1.6	6.1	15375
Marion	W. Va.	38.5	1.2	5.5	84.5	1.7	7.1	15270
Mineral	W. Va.	18.9	1.2	4.9	89.7	1.5	2.7	15720
Ohio	W. Va.	46.5	4.0	5.6	81.9	2.1	6.4	14845

TABLE 2. Similarity in Average Analyses of Different Seams in Jefferson County, Penna. (Moisture and Ash Free Values)

Name of Seam	V. M.	S	H	C	N	O	B.t.u/lb
Upper Freeport	37.0	2.4	5.5	84.8	1.6	5.7	15240
Lower Freeport	36.9	3.0	5.5	84.7	1.6	5.2	15240
Lower Kittanning	37.8	2.5	5.6	84.7	1.6	5.6	15165
Average	37.2	2.6	5.5	84.8	1.6	5.5	15215

TABLE 3. Typical Individual Analyses of Pittsburgh Seam Coal in Alleghany County, Penna. (abbreviated list)

As Received		Moisture and Ash Free							
Moisture	Ash	Volatile matter	Fixed carbon	Sulfur	Hydrogen	Carbon	Nitrogen	Oxygen	Heat Value B.t.u/lb
2.7	6.3	39.6	60.4	1.5	5.5	84.4	1.6	7.0	15180
2.9	4.4	38.0	62.0	1.2	5.4	84.6	1.7	7.1	15130
3.3	4.8	38.2	61.8	1.5	5.4	84.2	1.6	7.3	15180
2.9	6.2	38.6	61.4	1.7	5.5	84.7	1.7	6.4	15130
2.0	5.7	39.6	60.4	1.3	5.6	84.1	1.7	7.4	15070
3.2	8.5	39.2	60.8	1.2	5.5	84.1	1.6	7.6	15040
3.0	6.1	39.9	60.1	1.4	5.6	83.6	1.5	7.9	14980
2.5	6.4	37.2	62.8	0.9	5.5	85.7	1.8	6.1	15110
3.9	6.0	37.9	62.1	1.6	5.6	84.0	1.6	7.2	15000
3.2	7.5	36.7	63.3	1.6	5.6	84.1	1.7	7.0	15110
Average									
M 2-4									
A 4-9		38.5	61.5	1.4	5.5	84.3	1.6	7.2	15095

TABLE 4. Typical Individual Analyses of Upper Freeport Seam Coal in Westmoreland County, Penna. Showing Two Distinct Grades in the Same Seam and Area. (abbreviated list)

As Received		Moisture and Ash Free							
Moisture	Ash	Volatile matter	Fixed carbon	Sulfur	Hydrogen	Carbon	Nitrogen	Oxygen	Heat Value B.t.u/lb
2.7	7.7	30.0	70.0	1.4	5.1	87.0	1.4	5.1	15460
2.3	7.5	29.3	70.7	3.6	5.1	86.4	1.7	3.2	15450
3.2	12.6	29.8	70.2	4.2	5.1	85.7	1.4	3.6	15350
2.9	11.0	29.9	70.1	1.8	5.2	87.0	1.4	4.6	15380
3.0	8.2	27.7	72.3	1.1	5.3	87.6	1.4	4.6	15490
Average									
M 2-4									
A 7-13		29.3	70.7	2.4	5.2	86.7	1.5	4.2	15425
2.4	8.0	39.4	60.6	2.3	5.7	84.1	1.6	6.3	15180
2.7	7.9	38.9	61.1	4.0	5.6	84.1	1.5	4.8	15350
2.7	10.7	41.3	58.7	3.6	5.4	83.3	1.4	6.3	15130
1.7	8.1	39.2	60.8	1.6	5.7	84.6	1.8	6.3	15240
2.5	9.4	39.3	60.7	3.8	5.6	83.4	1.5	5.7	15110
Average									
M 1-3									
A 3-11		39.6	60.4	3.1	5.6	83.9	1.5	5.9	15200

usually be made by some item of a proximate analysis.

The analyses of the coal substance from several seams in the same area are usually more similar than the analyses of the coal from the same seam in different areas. A striking example of the variations in the basic analyses of the same seam in different counties is given in Table 1 which gives characteristic analyses for the Pittsburgh seam in counties of Pennsylvania, Ohio, Maryland and West Virginia.

Table 2 illustrates the similarity of the analyses of three different seams within the same county. In this case these three seams represent the bulk of the coal mined in this area and an average of these three seams gives a fair average for any coal from this county.

Table 3 is an abbreviated list of individual coal analyses typical of the Pittsburgh seam in Allegheny County, Penna., and shows the narrow limits of variation in the moisture and ash-free values within this area. The Pittsburgh seam contributes the bulk of the coal produced in this county and its average analysis represents the average for the county.

An unusual case of two distinct grades of coal from the same seam and county is shown in Table 4. A sharp classification here is difficult because of variations in sulfur content but the volatile and total carbon values are distinct.

Table 5 is a list of average moisture and ash-free analyses of coals from the principal producing counties of most of the coal bearing states. The list is in the approximate order of tonnage production. Thus, for example, Kentucky is the fourth largest producer and Harlan County is the leading county in the state. Perry,

TABLE V

AVERAGE ANALYSES OF COALS OF THE UNITED STATES

State and Counties	Moisture and Ash Free								As Received	
	Volatile Matter	Fixed Carbon	Sulfur	Hydrogen	Carbon	Nitrogen	Oxygen	B.t.u. per lb	Moisture	Ash
PENNSYLVANIA										
Alleghany - Butler - Greene	39.6	60.4	2.0	5.5	83.7	1.7	7.1	15070	2-5	4-13
Cambria - Clearfield - Center	24.6	75.4	1.9	5.1	88.2	1.4	3.4	15615	1-5	5-12
Washington - Fayette - Elk	37.8	62.2	2.4	5.5	84.8	1.6	5.7	15275	2-4	6-13
Fayette	31.4	68.6	1.0	5.2	86.0	1.5	6.3	15520	3-5	7-9
Westmoreland - Indiana	26.5	73.5	2.5	5.2	87.6	1.4	3.3	15630	1-5	5-12
Somerset - Tioga	23.5	76.5	1.9	4.8	88.6	1.6	3.1	15540	1-5	5-12
Jefferson - Westmoreland	35.4	64.6	2.1	5.4	85.0	1.7	5.8	15285	2-4	7-15
Bedford - Cambria	19.8	80.2	1.9	4.8	89.4	1.5	2.4	15665	1-6	5-12
Huntingdon - Somerset	17.1	82.9	1.4	4.6	90.3	1.4	2.3	15785	1-6	5-12
Sullivan	10.6	89.4	0.9	3.8	91.6	1.2	2.5	15445	3-4	10-15
Lackawanna - Luzerne	7.3	92.7	0.7	2.6	93.5	0.9	2.3	15100	2-6	6-16
Schuykill	2.0	98.0	0.9	2.1	93.9	0.8	2.3	14870	2-3	8-13
WEST VIRGINIA										
McDowell - Fayette	17.7	82.3	0.8	4.8	90.4	1.3	2.7	15710	2-4	3-6
Logan - Fayette	36.2	63.8	1.1	5.5	86.3	1.7	5.5	15340	1-3	4-8
Raleigh - Fayette - Mercer	18.5	81.5	0.7	4.8	90.1	1.4	3.0	15720	2-4	3-6
Marion - Kanawha - Harrison	40.9	59.1	1.5	5.6	83.9	1.6	7.4	15080	1-4	4-10
Monongahela - Greenbriar	30.2	69.8	0.9	5.2	87.2	1.6	5.1	15440	2-4	4-12
Ohio - Brooke - Marshall - Putnam	45.0	55.0	3.5	5.6	81.9	1.6	7.4	14820	2-5	5-11
ILLINOIS										
Franklin - Williamson	39.1	60.9	1.9	5.3	81.3	1.7	9.8	14500	8-12	8-12
Perry - Vermillion	43.4	56.6	1.7	5.4	80.4	1.7	10.8	14290	11-17	7-11
St.Clair - Madison	46.7	53.3	5.7	5.4	77.0	1.3	10.6	14130	9-16	11-20
Macoupin - Sangamon	46.3	53.7	5.5	5.4	77.5	1.4	10.2	14175	12-16	8-16
Saline	39.2	60.8	2.9	5.3	80.8	1.6	9.4	14750	5-15	7-12
KENTUCKY										
Harlan- Perry - Bell - Knox	40.2	59.8	1.1	5.6	83.5	1.9	7.9	14955	2-6	2-8
Pike - Letcher	37.8	62.2	0.8	5.4	85.2	1.6	7.0	15185	1-4	2-7
Muhlenberg - Hopkins	44.7	55.3	4.0	5.4	80.3	1.7	8.6	14445	4-10	5-12
Webster - Union	43.9	56.1	4.0	5.4	81.1	1.7	7.8	14630	4-10	5-12
Henderson - Davies	46.2	53.8	4.1	5.3	78.6	1.8	10.2	14130	4-10	5-12
Johnson (cannel coal)	57.0	43.0	1.3	7.4	82.5	1.3	7.5	15840	1-3	8-11
OHIO										
Belmont - Guernsey	45.2	54.8	4.4	5.6	80.2	1.5	8.3	14610	4-5	8-18
Jefferson - Guernsey	41.5	58.5	2.6	5.6	82.2	1.6	8.0	14830	3-7	5-12
Athens - Meigs - Hocking	41.6	58.4	2.7	5.5	79.8	1.3	10.7	14360	5-8	7-10
Noble - Tuscarawas - Perry	44.1	55.9	4.1	5.6	79.6	1.5	9.2	14480	3-7	5-12
INDIANA										
Pike - Greene - Sullivan	45.2	54.8	2.0	5.6	80.9	1.8	9.7	14500	10-14	6-12
Vigo - Knox - Vermillion	48.0	52.0	4.5	5.6	79.6	1.5	8.8	14510	6-12	7-12
ALABAMA										
Jefferson - Tuskaloosa	27.7	72.3	0.8	5.2	88.1	1.7	4.2	15625	2-5	3-10
Walker - Bibb - Shelby	38.0	62.0	1.0	5.4	84.3	1.7	7.6	15100	1-5	2-14
St.Clair - Jefferson	35.4	64.6	1.8	5.4	85.2	1.8	5.8	15250	2-5	4-12
VIRGINIA										
Wise - Russell	36.9	63.1	0.9	5.5	86.3	1.6	5.7	15410	2-5	4-9
Tazewell	17.8	82.2	0.7	4.8	90.4	1.2	2.9	15890	2-6	2-6
Lee - Scott	37.8	62.2	1.1	5.4	83.6	1.6	8.3	15085	3-6	3-9
Dickenson - Buchanan	31.2	68.8	1.4	5.2	87.3	1.8	4.3	15415	2-4	3-18
COLORADO										
Weld - Boulder	42.5	57.5	0.5	5.1	75.0	1.5	17.9	12935	17-30	3-6
Las Animas	36.5	63.5	0.7	5.5	84.9	1.5	7.4	15275	1-7	6-20
Huefano - Gunnison	40.7	59.3	0.7	5.5	80.6	1.6	11.6	14435	3-10	3-12
Routt - Fremont	43.0	57.0	0.9	6.2	76.6	1.3	16.0	13550	10-18	3-10
WYOMING										
Sweetwater - Hot Springs	41.8	58.2	1.1	5.3	77.3	1.5	14.8	13785	8-16	3-8
Sheridan - Carbon	45.3	54.7	0.8	5.1	74.1	1.3	18.7	12810	18-30	5-15
Lincoln - Sweetwater	43.4	56.6	1.1	5.4	79.8	1.5	12.2	14220	6-18	4-12
Carbon - Sweetwater	39.5	60.5	0.8	5.1	76.2	1.6	16.3	13260	15-25	4-7
MISSOURI										
Barton	38.0	62.0	5.0	5.5	83.0	1.4	5.1	15120	5-7	8-13
Bates	42.3	57.7	4.5	5.5	81.0	1.5	7.5	14700	7-12	11-15
Henry - Macon - Randolph	45.4	54.6	5.6	5.5	79.2	1.3	8.4	14370	9-16	8-16
Lafayette - Ray - Linn	46.2	53.8	5.2	5.6	78.6	1.3	9.3	14320	11-16	7-15
IOWA										
Appanoose - Polk - Lucas	47.9	52.1	6.3	5.5	77.0	1.5	9.7	14225	13-19	7-15
TENNESSEE										
Campbell - Claibourne - Anderson	40.2	59.8	1.7	5.6	83.3	2.1	7.3	14910	2-6	3-7
Morgan - Scott - Fentress	40.9	59.1	3.0	5.6	83.3	1.9	6.2	15030	2-6	3-7
Marion - Hamilton	31.1	68.9	1.5	5.4	87.3	1.6	4.2	15425	2-5	4-10
UTAH										
Carbon - Emery - Grand	45.8	54.2	0.7	5.7	80.3	1.6	11.7	14370	3-10	4-20
Summit - Uinta	45.3	54.7	3.5	5.4	76.2	1.2	13.7	13540	5-17	3-13
MONTANA										
Rosebud - Custer	44.4	55.6	0.8	4.4	71.7	1.1	22.0	12030	27-30	3-15
Musselshell - Gallatin	42.8	57.2	1.1	5.4	78.5	1.4	13.6	13915	4-14	6-30
Carbon - Fergus	40.6	59.4	3.3	5.1	76.0	1.4	14.2	13340	8-24	8-18
Cascade	35.0	65.0	3.8	4.8	77.8	1.0	12.6	13520	3-12	14-25
KANSAS										
Crawford - Cherokee	39.5	60.5	4.0	5.4	83.0	1.5	6.1	15030	2-8	8-12
Leavenworth	47.2	52.8	5.7	5.4	79.6	1.5	7.8	14430	10-12	12-16
NORTH DAKOTA										
Ward - Williams	47.6	52.4	0.9	4.9	72.1	1.1	21.0	12000	35-43	5-12
MARYLAND										
Alleghany - Garrett	18.2	81.8	1.6	4.7	89.3	1.7	2.7	15650	2-4	6-14
OKLAHOMA										
Le Flore	18.2	81.8	0.9	4.6	90.4	1.9	2.2	15560	1-3	6-12
Okmulgee - Tulsa	41.9	58.1	3.1	5.5	82.4	2.0	7.0	14900	2-8	4-10
Pittsburg - Latimer	40.0	60.0	1.1	5.5	84.0	2.0	7.4	15045	2-10	4-8
WASHINGTON										
Kittitas - King	43.3	56.7	0.8	6.0	80.5	1.9	10.8	14620	3-9	10-20
Pierce - King	39.4	60.6	1.0	5.9	82.5	2.0	8.6	14900	2-6	8-20
Lewis - Thurston	49.3	50.7	1.7	5.8	71.7	1.3	19.5	12600	16-30	6-23
Pierce	25.4	74.6	0.6	5.4	87.5	2.5	4.0	15530	2-5	9-15
ARKANSAS										
Sebastian - Logan	19.0	81.0	2.5	4.4	89.3	1.8	2.0	15495	2-4	6-12
Franklin - Johnson	16.1	83.9	2.5	4.2	89.4	1.8	2.1	15450	2-4	6-12
TEXAS										
Huston - Milam - Wood	53.3	46.7	1.2	5.3	72.8	1.4	19.3	12705	29-37	6-12
NEW MEXICO										
Colfax - Lincoln	43.1	56.9	0.9	5.7	82.6	1.5	9.3	14860	2-5	9-17
McKinley	47.2	52.8	0.9	5.5	79.2	1.4	13.0	13940	10-16	3-10

Note: States and Counties are listed in approximate order of tonnage production.

$$\text{Percent As Received} = \text{Percent Moisture \& Ash Free} \times \frac{(100 - \text{Percent Moisture plus Ash})}{100}$$

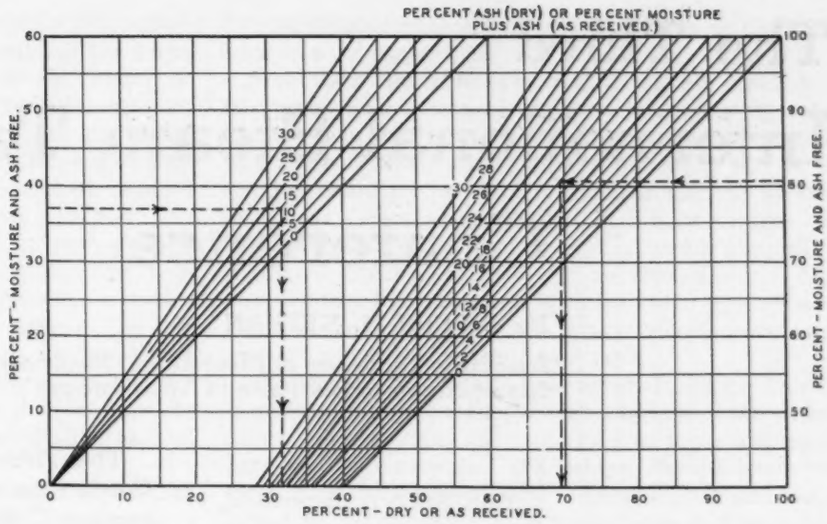


Fig. 1—Coal analysis conversion chart. Care must be taken to use proper values for ash and moisture

Bell and Knox Counties produce coal of similar composition. Where more than one distinct grade is mined in the same county, the name of the county is repeated and usually associated with some other county. For example, Fayette County in West Virginia produces at least three coals of different composition ranging in volatile matter from 17 to 37 per cent.

The moisture and ash values given in Table 5 are on an "as-received" basis to facilitate conversion of the moisture and ash-free values. The formula for conversion is given at the foot of the table and standard methods of conversion are available in any fuel handbook. The moisture and ash values are in most cases for mine samples and may not be representative of values for delivered coal after cleaning and air drying. Figs. 1 and 2 are given to allow graphical conversion when greater accuracy is not essential. In converting from one basis to another care must be taken to use the proper values for moisture and ash. For example, to convert from a moisture and ash-free basis to an "as-received" basis the sum of the moisture and ash on an "as-received" basis is required but to convert from moisture and ash-free to a dry basis, the percentage of ash on a dry basis is used.

Conclusions

In conclusion, it is desired to emphasize the importance of describing the source of a coal. If the source can be traced through state and county to seam and mine, a very reliable and complete analysis can be set up for any given moisture and ash content by referring to reliable moisture and ash-free averages of coal from the same source. The averages given in Table 5 covering, in some cases, several counties cannot of course apply with equal accuracy to each mine in these counties. They have been kept within reasonable limits and as stated are for use in the absence of and as a check on specific data.

Subsequent articles will be prepared and published dealing in more detail with the principal producing states and in these articles, a sharper classification will be made of the seams in the coal counties.

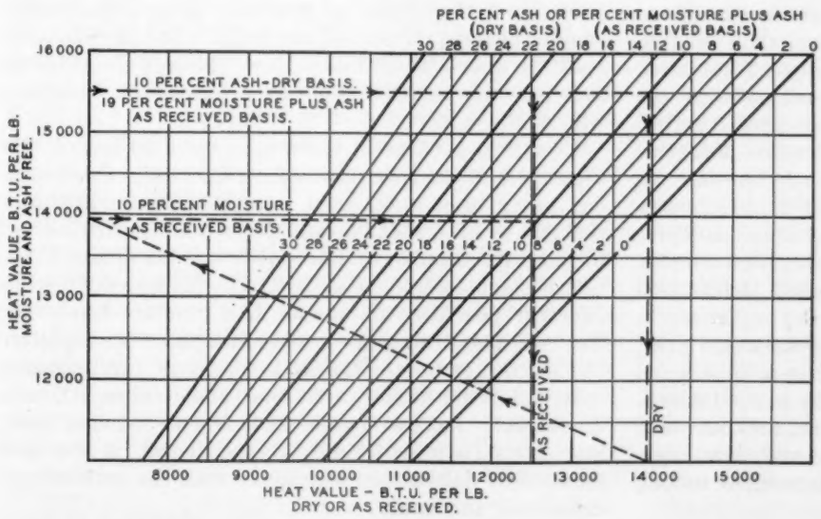

PER CENT ASH OR PER CENT MOISTURE PLUS ASH
(DRY BASIS) (AS RECEIVED BASIS)
10 PER CENT ASH-DRY BASIS.
19 PER CENT MOISTURE PLUS ASH AS RECEIVED BASIS.
10 PER CENT MOISTURE AS RECEIVED BASIS.
AS RECEIVED
DRY
HEAT VALUE - B.T.U. PER LB. MOISTURE AND ASH FREE.
HEAT VALUE - B.T.U. PER LB. DRY OR AS RECEIVED.

Fig. 2.—Heat value conversion chart for approximate determinations

The Third International Steam Tables Conference

By JOSEPH H. KEENAN

Associate Professor of Mechanical Engineering, Massachusetts Institute of Technology

The Third International Steam Tables Conference was held in this country September 17 to 22, inclusive, with delegations representing England, Germany, Czechoslovakia and the United States. Successive sessions were held at the Bureau of Standards, Washington, the Massachusetts Institute of Technology, Cambridge, and at New York. As a result of this conference close agreement was reached as to the critical value, the enthalpy of saturated vapor and the tolerance on enthalpy of superheated steam reduced to one-third the value previously agreed upon at the London Conference. Professor Keenan who has long been active in this work and who was a member of the American delegation, was asked to prepare for the readers of COMBUSTION his impressions of the accomplishments of the recent conference.—Editor.

PERSISTENT, impersonal, passionless is the scientist's search for truth—according to those who know nothing about it. But those who have sought the perfect form of the scantly-clad goddess know that she encourages no Platonic suitors. Among her favorites, it appears, are a small group of scientists who study the properties of water and its vapor. Their labors are Herculean, their persistence more than human, their passion for truth is warm. Each has seen enough to form an image of his goddess, and each believes his image to be a photographic likeness.

A project was set on foot, the object of which was to bring these suitors together with their bits of images that they might piece them together into one composite photograph. But would anything come of it? Surely no session could survive even the first conflict over a detail of profile. Had they been mere photographers some result might have come of it—but these were suitors.

From such doubtful beginnings have grown the International Steam Tables Conferences. They have succeeded only because of a unifying objective: to reduce departures in published data from the true values of the properties of steam. No controversy, no conflict, however contentious, could compare in importance with this objective—so the objective ruled the conference.

The London conference in 1929 started with a clean slate. It found that it was necessary to devise its own methods and its own procedure because there was behind it no tradition of program or policy. Much of the success of that conference and of subsequent ones is due to the wise policies adopted there. Its method was to choose a certain limited number of states of steam or water separated by suitable intervals and covering the range of interest to the engineer and the scientist, and to establish at each of these states accepted values of several properties. The accepted value is in each instance the nearest approach to the true value of that property which can be made in view of the various opinions represented. As a rule, it is arrived at as a weighted average of proposed values, the weighting being determined through estimates of the relative reliability of the methods by which the proposed values are obtained. Next, a tolerance is chosen which when added to or subtracted from the accepted value establishes limits beyond which, in the opinion of the conference as a whole, the true value does not lie. Both the accepted values and their tolerances are established by unanimous agreement among the delegations.

In such fashion the conference produces a skeleton table of the properties of water and its vapor with tolerances. Any steam table whose values fall within these tolerances at all points is considered an international steam table. Of course, the conference can inflict no penalty on the author of a steam table whose values wander beyond the conference limits. It can only withhold its approval of his work. The authority of the skeleton table rests solely upon the prestige of the experts who establish it.

Doubtless because of the great names on its roll, the expertness of the International Steam Tables Conference has never been questioned. England has contributed the names of Callendar and Egerton; Germany's list includes Knoblauch, Mollier, Henning, Jakob and Koch; Czechoslovakia adds Havliček and Miskowsky; while America provides the names of Osborne, Davis and Keyes. The third and most recent conference regretted the absence of Doctor Havliček who could not be spared from industrial affairs in Europe, and it missed Doctor Knoblauch, Doctor Jakob and Doctor Mollier from among its German friends. Nevertheless, it was well manned by delegations who spoke with the authority of experience and study.

Some idea of the progress toward international agreement can be had by comparing the results of the First, or London, Conference with those of the Third, or American, Conference. It should be remembered, however, that the London Conference by no means represented the extreme of disagreement between various authorities. Agreement was more than half realized before the First Conference was called. In fact, five years earlier it would have been difficult to find a piece of common ground large enough to provide standing room for the delegates. Differences between steam tables were so great that frequently it was claimed that one table represented laboratory steam and another power plant steam—or one table was for flowing steam, another for stationary steam. It is significant that we hear less about different kinds of steam the fewer experimental differences we have to explain away.

At London even the region of saturated liquid and vapor was approached gingerly. We find accepted values given for only eight different temperatures because the possibilities for argument were too great to permit more to be settled within a week. The American Conference tabulates forty-two different temperatures. In London the critical region was discreetly ignored by stopping the table twenty degrees short of it; the American Conference tabulation extends presumptuously to within a fraction of a degree of the critical point, and it derides the bitterness of earlier controversy by quoting two experimentally determined values of the critical temperature, one German and one American, which agree within one-tenth of one degree. The London tolerance on the specific volume of saturated liquid at 350 C (662 F) was almost two per cent—the American tolerance is one-thirtieth of one per cent. At the same temperature the tolerance on the enthalpy of saturated vapor has been reduced from seven calories per gram to two calories per gram.

The long distance we have come from London is illustrated by another example. At London the specific volume of saturated liquid and vapor and the enthalpy of saturated liquid and vapor, all four, were independently discussed and independently chosen. In the American Conference it was recognized that freedom of choice could be exercised in only three of the four cases and that the fourth must follow from the Clapeyron relationship.[1] This conclusion was a necessary consequence of the extraordinary agreement between recent independent measurements of vapor pressure at the Bureau of Standards, at Massachusetts Institute of Technology and at the National Physical Laboratory in England. The three sets of data spread about a mean less than 2/100 C over most of the experimental range. And so the enthalpy of the saturated vapor was settled before it was discussed.

Enthalpy of superheated steam proved to be the most troubled water the American Conference had to navigate. At bottom the difficulty was excessive data. There were direct measurements by the condensation method from England, more of the same kind from Czechoslovakia, specific heat measurements from Germany and values deduced from specific volume measurements made in America. Attached to each of these was the pride and aspiration of a nation, and compromise gave pain to patriotism. Nevertheless, agreement was reached and tolerances approximately one-third as large as those at London were established.

From the steam tables of the past it might be concluded that water as a substance begins to be interesting only when it commences to boil. Our tables for superheated steam are detailed and complete but they end in a stepped boundary on the left which is marked by the saturation tables. Beyond that in desolate wastes of white paper the compressed liquid has lived in obscurity. At the American Conference it came into its own. The vast white spaces are now furnished with appropriate numbers and tolerances for every temperature and pressure included in the superheat table.

Of course, the Third International Steam Tables Conference was not occupied with numbers to the exclusion of all else. Equally important to those who took part was the renewal of friendships, formed, many of them, five years ago or more. Their travels and their labors as a conference were adventures in friendship; their work had that vigor and effectiveness that comes from understanding between workers; and their last evening together was suggestive of the carefree comradeship of schoolfellows at the close of examinations.

[1] $dp/dT\ (v_g - v_f) = (h_g) - h_f/T$.

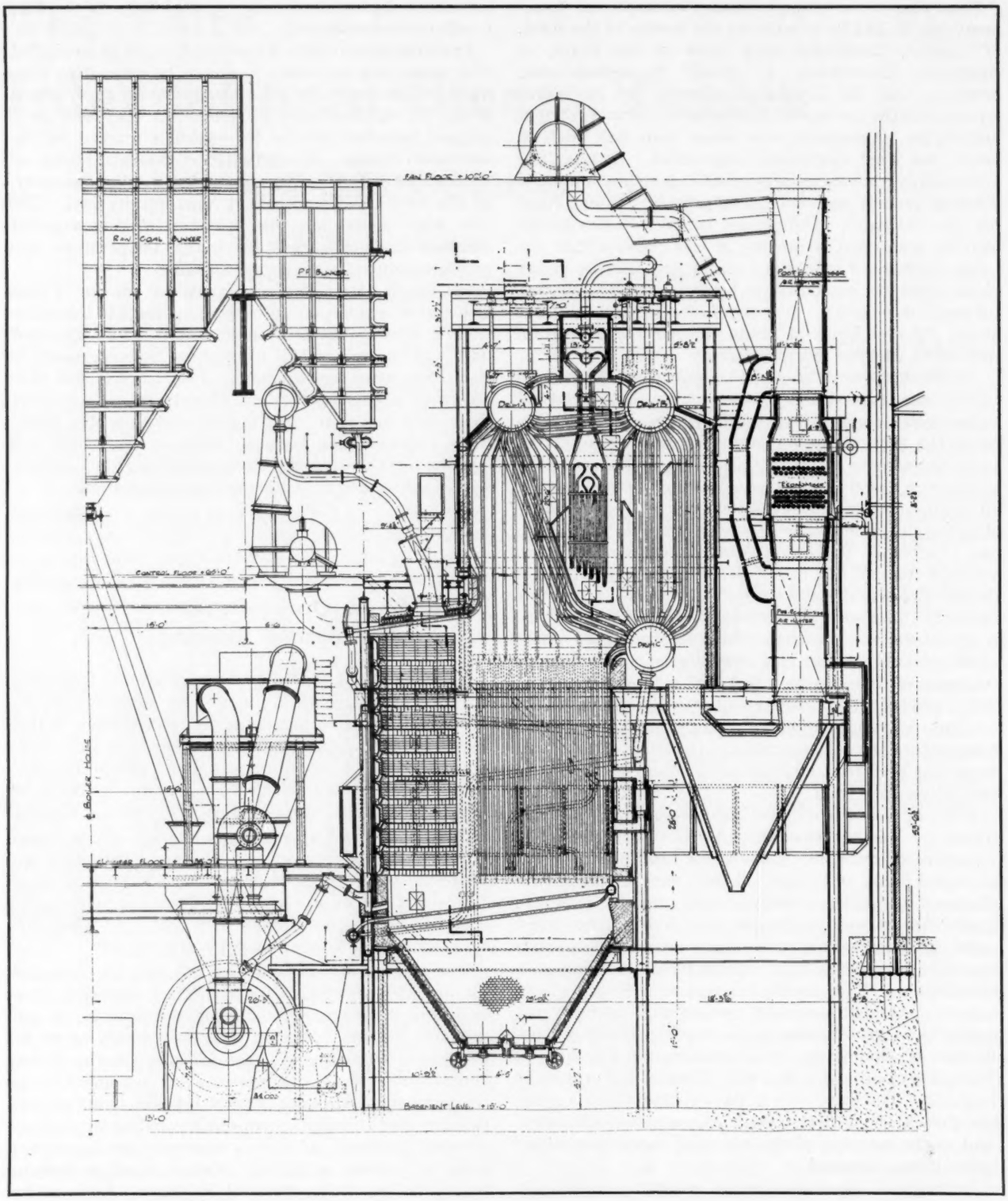
Power Show Questionnaire Reveals Potential Buying

As preparations for the Eleventh National Exposition of Power and Mechanical Engineering progress there is a widening belief that, in view of the large amount of relatively obsolete equipment now in service, this year's show will reflect a keener interest among prospective purchasers who will attend with the purpose of becoming familiar personally with advances in design and practice.

In order to check up on this, an inquiry, over the signature of the Chairman of the Advisory Committee, was addressed to 965 persons who attended the 1932 show. Two questions were asked: (1) "Do you contemplate the purchase of new equipment?" and (2) "What type of exhibits would be of greatest interest to you?"

The number of replies received to date has been 184, the majority of which were from chief engineers, plant engineers, plant managers and superintendents. A considerable number indicated that they would be in the market for purchases. Of these five are planning to buy boilers, ten plan to buy fuel burning equipment, seven will want steam turbines or other types of prime movers, thirteen desire auxiliary equipment, nine instruments and control equipment, three air compressors, and five valves, traps and steam specialties. Others signified their intention to purchase electrical apparatus, tools, power transmission equipment, refrigeration heating, ventilating and air conditioning equipment.

As might be expected a wide diversity of interest was indicated as to the types of equipment which the signers wished to see exhibited; in fact, they covered the whole power plant and allied services. In addition, interest was shown in superimposed equipment for low-pressure industrial plants, in high-pressure industrial power equipment, low-pressure plants of 200 lb and in the modernization of existing plants.



Cross-section of boiler unit, Tir John Station, Swansea, Eng.

This station was described in the September issue of COMBUSTION, but unfortunately the boiler cross-section was delayed and did not arrive until after the paper went to press. It is reproduced here because of its several features and because of the interest aroused by the original article. Briefly, these boilers have a normal rating of 240,000 lb of steam per hour at 625 lb working pressure and 850 F. Each boiler has a 10-ton ball mill feeding twelve straight-shot vertical Lopulco burners. The side and rear walls of the furnace and the top arch are water cooled and there is a double slag screen at the bottom. The front wall below the arch is of the refractory air-cooled type, air being admitted at each side and led through ports into the furnace. Each unit has an economizer, plate-type air heater, one induced-draft and two forced-draft fans.

Early Reasons for Soda Conditioning of Boiler Feedwaters

By CYRUS WM. RICE

Water Chemist and Engineer

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A review of early opinions, some dating back fifty years, shows that the use of various soda compounds as conditioning agents for preventing boiler scale was well understood and that di-sodium and tri-sodium phosphate were discussed at some length by Cary in 1899. The essential difference between these early discussions and those of more recent date is that the former dealt mostly with the prevention of calcium sulphate deposits whereas modern operating practice has made it necessary to employ more exacting plant and laboratory control for preventing corrosion, caustic embrittlement, steam contamination and certain troublesome silica formations.

WITHIN recent years, discussions covering the chemical conditioning of boiler feedwaters has created more or less confusion in the minds of some boiler operators as to the real intentions back of such practices. A review of some early opinions covering the use of soda conditioning agents should materially clarify this issue. That the use of commercial sodas for the prevention of boiler scale is a very old practice, is readily shown by reviewing the published records of the past on this subject.

A review of many of these shows that soda ash was employed for both preventing and removing incrustations in steam boilers as early as 1883. A British patent was then granted S. Lattuda for this purpose.

In 1884 two articles—one by Bergk and a second by A. M. Friedrick, dealing with the uses of soda ash for the prevention of boiler scale, appeared in the *Proceedings of the Institute of Civil Engineers*.

Wm. MacNab and A. H. Bickett, in the May 20, 1886, issue of the *Journal of the Society of Chemical Industry*, laid special stress on the value of this chemical and of caustic soda for feedwater conditioning purposes. In this article the authors said:

"Where this (soda ash) is employed to precipitate lime and magnesia from the water before it is introduced into the boiler, an excess must be used to combine with the free carbonic acid in the water forming sesqui carbonate and the treated water then contains excess of alkali which is objectionable for most purposes, besides which the precipitation is incomplete unless heat be also employed.

"The lime and caustic soda removes practically all the hardness, both temporary and permanent, and does its work without the aid of heat and gives a water containing only soluble soda salts and no excess of alkali.

"Carbonate of soda is provided by the caustic soda and by the carbonic acid usually present in the water, but only so much caustic soda is added as is requisite to decompose the sulphates, chlorides, etc.

"Where permanent hardness is excessive it becomes necessary to supplement the caustic soda with soda ash."

This employment of caustic soda for absorbing CO_2 with the resulting formation of nascent carbonate of soda for the prevention of calcium sulphate deposits, constitutes some of the best practices today in the water conditioning processes.

Vero C. Driffield, in the March, 1887, issue of *The Journal of the Society of Chemical Industry*, is even more positive in his remarks about the use of soda ash and other anti-incrustators. Excerpts from his paper follows:

"This solid matter contained in the feedwater generally consists mainly of the carbonates of lime and magnesia and sulphate of lime.

"The carbonate of lime and magnesia, however, become objectionable if the flues are not allowed to cool well down before the boiler is blown off.

"Any sulphate of lime in the feedwater must be totally decomposed, otherwise the hard incrustations formed by the precipitation of this salt will incorporate itself with the lime and magnesia and so prevent the easy removal of the latter salt.

"The presence of sulphate of lime in the feedwater is a much more serious matter than is that of the carbonate, as sulphate of lime deposits itself, as is well known, in the form of a hard scale which tenaciously adhers to the plates and is very difficult to remove.

"The object of an anti-incrustator is to prevent as far as possible the precipitation, in the form of a hard scale, of the solid impurities contained in the feedwater and to neutralize any free acid which may be formed by the decomposition of the salts.

"Whatever substance will best accomplish this without

being otherwise injurious is the best anti-incrustator to use."

I do not know of another early authority that has shown the same complete knowledge of the soda conditioning of boiler feedwaters as has Mr. Driffield. The pertinent facts in connection with his conclusions are that he knew,

1. That carbonate of lime and magnesia became objectionable under conditions where they are allowed to solidify through crustal growths;
2. That any anti-incrustators in use must be added in sufficient quantities to the feedwater to prevent totally depositions of calcium sulphate;
3. That the presence of any calcium sulphate in the feedwater is a serious matter;
4. That whatever anti-incrustator would best prevent depositions of calcium sulphate in boilers and neutralize all acids formed through the decomposition of salts, is the best to employ.

His language in this connection is positive and it is all the more surprising in that his knowledge on this subject was expressed forty-seven years ago.

A boiler feedwater analyst, the late Albert A. Cary, nearly the equal of Driffield, wrote, in the Dec. 7, 1899, issue of the *American Machinist*, as follows:

"The principal scale-making impurities precipitated in boilers are carbonate of lime, carbonate of magnesium, sulphate of lime, and sulphate of magnesium, and although there are other precipitates, none of these alone will be sufficient for the present consideration.

"The carbonate of soda (soda ash) is used to act upon the sulphate of lime and magnesium in the following chemical formulas:

$$NaSO_4 + Na_2CO_3 = CaCO_3 + Na_2SO_4$$
$$MgSO_4 + Na_2CO_3 = MgCO_3 + Na_2SO_4$$

"In the presence of CO_2 these calcium and magnesium products become the more soluble bicarbonates.

"Boiling and treatment with the soluble hydroxides reduces the bicarbonates to the more insoluble carbonates.

"There are other compounds falling under this classification of known chemical composition which are more satisfactory than those named above, such as the di-sodium and tri-sodium phosphates, the latter being available in both the hydrous and anhydrous state. The latter is less bulky and its reactions with the sulphate of lime is shown by the following formulas:

$$2Na_3PO_4 + 3CaSO_4 =$$
(tri-sodium phosphate + calcium sulphate)
$$Ca_3(PO_4)_2 + 3Na_2SO_4$$
(tri-calcium phosphate + sodium sulphate)

"The phosphate of lime after this reaction, precipitates as a slushy mud, making at the most a very weak crust, while the sulphate of soda remains in solution as previously described."

Cary, in both the reactions shown at the time, and in his written conclusions, knew exactly the purposes for which the chemicals were employed. There was no guesswork on his part, as he not only mentioned the principal constituents of lime and magnesium for which treatments were used for boiler conditioning purposes, but in addition referred to other scale-producing precipitates. His treatments for preventing objectionable boiler deposits also varied, as he included crystalline and anhydrous di- and tri-sodium phosphate, mentioning the latter class as more satisfactory than soda ash.

Augustus H. Gill, in the January, 1906, issue of *Power*, also discussed the value of various soda treatments. His statements in this connection were:

"It (soda ash) transforms the sulphates into carbonates changing what would be a hard adherent scale of gypsum into powdery calcium carbonate which is easy to blow down.

"Sodium aluminate made by fusing soda ash and alumina together may for practical purposes be regulated as acting like caustic soda.

"In addition, aluminum hydroxide is thrown down as a flocculent precipitate which possesses to a marked degree the property of clarifying waters; hence it should carry down not only the carbonate of lime and magnesia, but organic matter such as humic acid, tannic acid, clay, mud, etc., in such a condition that it can be readily removed by blowing down."

This same author in his reference to phosphates says: "By its use. . .the waters are both softened and clarified. The lime and magnesium compounds are changed into phosphates which are insoluble, thus taken out of solution and are flocculent precipitates which drag down any substance in suspension as clay, mud, etc."

Gill appeared equally as well schooled as Cary in the use of soda ash and phosphates, and in addition had some knowledge of the value of sodium aluminate as a boiler conditioning agent. Most references up to now have laid stress on the use of soda ash for the conditioning of boiler feedwaters, both through water softeners and directly within boilers. Other articles on this use appeared in many publications before and after the dates given, but a review of these here would add nothing of importance to the conclusions of the authors already quoted.

Sodium Aluminate Discussed

The first article devoted exclusively to sodium aluminate appeared in the October, 1898, issue of the *Journal of the American Chemical Society*. The contribution was from the chemical laboratory of the Case School of Applied Science and was discussed by Chas. F. Mabury and E. B. Batzley under the heading of "Sodium Aluminate as a Means for the Removal of Lime and Suspended Matter from Waters for Use in Boilers." The following excerpts from this article clearly indicate the conclusions of the authors:

"In stationary boilers the deposition of scale may be avoided, at least in part, by using some one of the many so-called scale preventatives, if the boiler is in charge of an intelligent engineer.

"The wide variations in the composition of boiler scale are dependent on the differences in the water.

"Evidently successful purification depends on removing completely the suspended matter as well as the precipitation of the lime and magnesia.

"...sodium aluminate should fulfill the conditions demanded and in trying this reagent we find it meets all requirements."

Work carried out by these investigators on different kinds of water showed reductions in lime of 97.6 per cent and in magnesia of 93.2 per cent, with theoretical amounts of sodium aluminate added and with thirty-six hours' standing. These reductions agree with the latest

practices in external lime-soda softener operations, especially in the cold process where the treatments are correctly balanced. Under such circumstances it is not uncommon to reduce the total actual calcium and magnesium in the finished water to about 1/2 grain, terms calcium carbonate.

Martin L. Griffin, in a paper delivered May 5, 1899, before the New York Section of the American Chemical Society discussed the use of boiler water conditioning chemicals generally. His reference to sodium aluminate was:

"In every case the action of the aluminate was comparatively slow and in the case of the lime salts did not give satisfactory results.

"It proved more effectual in the removal of magnesium salts."

This conclusion reached 35 years ago is in agreement with that of today as it is a well-known fact now that the presence of magnesium is definitely necessary before the most satisfactory boiler feedwater can be produced with sodium aluminate. In fact, magnesium is sometimes added to waters to improve results where it is found deficient.

Claims for Sodium Fluoride

Griffin further says in connection with the use of other conditioning chemicals that,

"Sodium fluoride is much to be preferred in waters containing calcium sulphate and chloride and is of no value in the removal of magnesium sulphate and barium hydroxide. It is most serviceable in the treatment of acid mine waters."

Dr. Chas. A. Doremus in 1890 also advanced certain claims covering the use of sodium fluoride which Griffin confirmed later. Up to now the reasons for using phosphates as conditioning agents was mentioned in connection with other chemicals all by the same writer. Reference alone to the use of phosphates by earlier authorities should prove of interest.

The first published record covering the use of this class of materials dates back to April 12, 1849. It was contained in a British patent granted to J. Horsley on the use of sodium phosphate for improvements in preventing incrustations in boilers.

Again in August of the same year H. Ogston was given a British patent to treat waters containing compounds of lime or other analygeous substances in solution and to "render available such waters for domestic and for manufacturing purposes." This claims the use of phosphoric acid. The language covering its application is specific. This follows:

"Supposing the water intended to be treated to contain sulphate or carbonate of lime, I ascertain the proportion of such ingredients and supply to the water as it is being discharged into a reservoir, a chemical equivalent for such impurity of phosphoric acid in the form of a soluble compound, admitting the latter to the water through a regulated supply cock."

In January, 1888, Geo. Edward Davis, in another British Patent, claims the use of tri-basic phosphate according to the hardness in the water. The claims in connection with both the 1849 and 1888 patent grants shows how early users of phosphates recognized the necessity of treating waters according to the amount of hardness it contains. Remarks of other writers on this use of phosphates continue.

W. S. Mahlie, in the February, 1920, issue of *Railway Mechanical Engineer*, in discussing the value of all kinds of soda conditioning agents said:

"The precipitates of sludge obtained from the action of phosphates are very light and flocculent and are easy to blow out of the boiler." He further said, "It is claimed by some that sodium phosphates are the most efficient boiler compounds in use."

The value of producing sludgy products with phosphate treatments was certainly recognized in many early discussions on this subject. This is again in agreement with present day practices.

Other interesting remarks having a direct bearing on this subject were made by the editor of *Power* in the September, 1902, issue, and by A. McGill in the April 15, 1904, Canadian issue of the *Journal of the Society of Chemical Industry*. The first mentioned discussed the influence of evaporations on scale formations, and observed that,

"When the water has dissolved all of a substance that it will hold in solution it is known as a saturated solution, having reached the point of saturation. Any substance in excess of what the water will hold in solution will deposit....In the steam boiler it will lie on the bottom of the tubes of a water tube boiler and on the sheet of the tubular boiler and is a tenacious heavy mass—a perfect non-conductor lying between the water and the iron."

Importance of Soluble Combinations Existing in Boiler Water

McGill's remarks cover another phase of this subject and are interesting in that they embody a very sensible conclusion regarding the manner in which soluble combinations should be considered to exist in a water. His remarks on this follow:

"In the light of ionization theory it is incorrect to speak of salts in solution in the ordinary sense. What is really important to us for present purposes is not the way in which acids and bases are combined in solution, but in what combinations they separate out, under the conditions of steam making or of softening processes."

More recent conclusions along this same line were expressed in a letter by the writer to a client back in 1921. This was made in connection with a request for information as to the value of a certain equipment for preventing boiler scale. The exact wording of this was:

"The real cementing or scaling substances in a water are soluble in the mass of water they attempt to filter and are only thrown out in a structural form as the water flashes into steam, which can occur only over the steam generating surfaces.

"To remove the suspended matters through filtration would only tend to increase the density or imperviousness of the resulting deposits to water.

"For waters containing such matters in solution, a chemical treatment for their entire precipitation as insoluble matter is the only way to prevent scale."

Any engineer can prove these conclusions by comparing the analyses of deposits from fire-exposed tubes

with deposits from tubes away from the fire. With untreated or under-treated waters the percentage of calcium sulphate in the tubes exposed to the radiant heat of the fire always exceeds the same constituent in the tubes away from the fire.

In summing up the conclusions on the subject matter they are little different than those of today in that the earlier authorities—

1. Employed the same CO_3 and PO_4 radicals for preventing depositions of calcium sulphate;
2. Recognized the fact that the soda treating agents containing these radicals had to be used in excess of the sulphate hardness in a water.
3. Held the same opinion about scale formations;
4. Knew of the beneficial influence of magnesium in the presence of a sodium aluminate treatment;
5. Were acquainted with the effect of certain boiler operations in hardening sludge and the necessity for the complete conversion of all scale-producing salts into sludgy muddy products.

In this whole comparison between the earlier and present discussions there is one prominent difference, and that is the earlier authorities are definitely negative as to the part silica and silica compounds played in causing objectionable boiler deposits. Today this is an extremely important issue, largely because of the greater refinements in treating and greater ratings and pressures under which so many boilers are now operating. Another phase of this work which had rather a prominent place in the early conditioning of feedwaters, and which has not been referred to here, was the use of colloids.

Colloids Now Receiving Attention

These were included in many patented boiler compounds and in almost as many different forms. While this was the case their knowledge as to how colloids prevented unsatisfactory boiler deposits was rather hazy. Within recent years this phase of the subject has been given more scientific attention and the limiting beneficial influences of colloids and the degree of their application are better understood.

Getting down to the basic reason for all this soda conditioning of boiler feedwaters, whether it applies to the earlier practices or those of today, it resolves finally into the maintenance of calcium-free boiler concentrates. The reason for this is that magnesium is first precipitated in the boiler concentrates as an insoluble hydroxide with a soda treatment before the remaining calcium can possibly be removed. Again, calcium, when present, is the only constituent outside of silica which deposits because of its evaporations to the point beyond its solubility. The completeness with which calcium can be removed from the concentrates is largely dependent on the excess amount of the CO_3 or PO_4 radicals, or both, that are carried in boilers and uniform maintenance of these in the water within the boilers. There are limits to which the maximum excesses should be carried as any chemical treatment over that required to produce the desired effect constitutes a chemical waste.

Accurate dependable methods for regulating the treatment of boiler concentrates under steaming conditions are therefore necessary to prevent this waste on the one hand, and to maintain correct conditioning on the other. While the use of excesses for converting the hardness in waters to sludgy, muddy products was common practice between the two periods, the scientific regulation of the treatments under steaming conditions is of more recent origin.

The earliest personal experience of the writer in the use of a soda control method dates back to 1901. At that time it was the practice to keep a record of the pht. alkalinity in the boiler concentrates and regulate the soda dosage according to this and results of the internal boiler inspections as made when the units came down for cleaning.

Between 1905 and 1907, after determining the inadequacy of any prior existing methods for controlling treatments through softeners and within boilers, the practice of analyzing the blowdown water was first inaugurated. This at the time included both quantitative and qualitative determinations for calcium, magnesium, sulphates, chlorides and the soda treating agents. This change,

1. Gave a definite yardstick for measuring the daily dosages without having to shut down a boiler;
2. Magnified the effects which over- or under-treatments, impurities and pressures had on the results;
3. Clearly indicated the degree of soda excesses and changes in treatment needed to maintain calcium-free boiler concentrates.

Within later years research work has been active in the development of simplified and accurate ways for both plant and laboratory determinations, all for the purpose of maintaining the practical maximum protection against all water impurities in the steam power plant. The radical changes within a comparatively few years to the high pressures, superheats and ratings of today, has made this necessary. Under the circumstances while the early reasons back of the soda conditioning of boiler feedwaters was only intended to prevent calcium sulphate deposits within boilers, the changes in operations has made it necessary to employ more exacting controls for preventing corrosion, caustic embrittlement, steam contaminations and the more troublesome silica formations.

In concluding let me say that dependable mineral analyses of every sample that has any bearing on the conditioning of the feedwaters for a specific object or objects proves the best guide for reasoning correctly in this work.

An Attractive Power Program

The program committee of the Metropolitan Section (New York), A.S.M.E., has announced a power evening at the Engineering Societies Building on Wednesday, October 24 at which three outstanding papers will be presented. These are "Slag Bottom Furnaces Experiences at Hell Gate," by J. J. Grob, engineer of tests United Electric Light and Power Company; "Superheat Experiments at Hudson Avenue," by W. H. Sperr, assistant plant equipment engineer, Brooklyn Edison Company; and "Effect of Turbine Overload on Heat Rates," by D. C. Weeks, station efficiency engineer, Brooklyn Edison Company. Because of the importance of these subjects a large attendance is expected.

A Simple Method for Humidity Computations

By C. HAROLD BERRY Professor of Mechanical Engineering,
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The engineer often needs to know the weight of water vapor accompanying one pound of air, or the weight of air in one cubic foot of atmosphere, or the total weight of one cubic foot of atmosphere. This paper presents a method of computing any or all of these results for combustion or fan calculations that is believed to be simpler and easier than the method usually used. It also serves to compute directly results that have otherwise to be found by cut-and-try methods. This is the third of a series of articles relative to humidity computations, the first and second of which appeared in the August and September issues, respectively.

HUMIDITY computations can be materially simplified through the use of two simple equations. One relates the specific humidity and the total and vapor pressures; the other provides a direct means of computing the density[1] of the mixture. These equations will be presented, their use will be illustrated by two numerical examples, and their derivations will follow.

$$\mathbf{s} = \frac{p_v}{1.61\,(B - p_v)} \tag{1}$$

$$p_v = B\left[\frac{1.61\,\mathbf{s}}{1 + 1.61\,\mathbf{s}}\right] \tag{2}$$

$$d_m = \frac{B - 0.38\,p_v}{RT_d} \tag{3}$$

where B = barometric pressure
p_v = actual vapor pressure[2]

NOTE.—Both of these pressures must be in the same units, which may be any whatever.

$\mathbf{s}$ = specific humidity (pounds of vapor per pound of air)[3]
d_m = mixture density, pounds of air-plus-vapor per cu ft
R = gas constant for air = 0.370 for pressure in lb/sq in.
0.754 for pressure in inches of mercury at 32 F
T_d = dry bulb temperature, F absolute.

Equations (1) and (2) are actually the same equation, solved for different quantities for convenient application to two types of problems. Equation (3) provides a simple method of computing mixture density.

In the first type of problem, we start with psychrometric data or with assumed temperature and relative humidity, and desire to compute specific humidity or densities. In the second type of problem, we start with values of temperature and specific humidity, and desire other results.

Example of the First Type

The quantity of air supplied to a furnace is known from fuel and gas analyses, or from an assumed excess coefficient. It is desired to know how much water vapor accompanies this air. Or, for the selection of a draft fan, it is desired to know the volume of atmosphere containing a stated weight of air. Or, again, in testing a fan, it is necessary to know the density of the atmosphere, that is, air plus vapor. The problem is stated in terms of psychrometric observations, or in terms of assumed dry-bulb temperature, relative humidity and barometer. This numerical example is based on observed data, and contrasts the proposed method of computing with the usual method, where the two differ.

Observed data

t_d = 78 F
t_w = 63 F
B = 27.83 in Hg at 32 F = 13.67 lb per sq in. abs.

From the Keenan Steam Tables, the pressure of saturated vapor at t_d and t_w is found to be

p_d = 0.474 lb per sq in. abs.
p_w = 0.285

Compute the vapor pressure

$$p_v = p_w - \frac{B}{30}\,\frac{(t_d - t_w)}{90} = 0.285 - \frac{13.67}{30} \times \frac{15}{90} =$$

$$0.285 - 0.076 = 0.21 \text{ lb per sq in.}$$

Compute the density of air in the atmosphere

Partial pressure of air = $B - p_v$ = 13.67 − 0.21 = 13.46 lb per sq in. abs.

$$d_a = \frac{B - p_v}{RT_d} = \frac{13.46}{0.370 \times 538} = 0.0676 \text{ lb per cu ft}$$

At this point, the proposed method substitutes two steps for four steps required by the usual method.

[1] The word *density* is used throughout this paper to denote the pounds of matter in a cubic foot, whether it be the pounds of air alone, or of vapor alone, or of the two together. The respective terms are air density, vapor density and mixture density.

[2] Computed from psychrometric data by means of Apjohn's equation, for example. See "A Comparison of Psychrometric Equations," COMBUSTION, August 1934, page 24.

[3] The name *specific humidity* is sometimes used for other quantities, such as vapor density (pounds of vapor per cubic foot), but the meaning here given is perhaps the one most widely used (often in grains of vapor per pound of air). The use of the term *absolute humidity* for this or any other concept is to be discouraged because it appears in the literature with diverse meanings, and hence is a vague term.

Proposed Method	Usual Method[4]
Compute the specific humidity $s = \frac{p_v}{1.61(B-p_v)} = \frac{0.21}{1.61\times 13.46}$ $= 0.0097$ lb vapor per lb air	Compute the relative humidity $r = \frac{p_v}{p_d} = \frac{0.209}{0.474} = 0.441$ From the steam tables find the specific volume of saturated steam at t_d $v_d = 674.5$ cu ft per lb
Compute the vapor density $d_v = d_a \times s = 0.0676 \times 0.0097$ $= 0.00066$ lb per cu ft	Compute the vapor density $d_v = \frac{r}{v_d} = \frac{0.441}{674.5} = 0.000654$ lb per cu ft Compute the specific humidity $s = \frac{d_v}{d_a} = \frac{0.000654}{0.0676}$ $= 0.0097$ lb vapor per lb air

[4] In the usual method, the steps are such that there is danger of accumulating errors; it is therefore desirable to carry three significant digits. This gives intermediate results that appear to be more accurate than the data justify, as has been pointed out in a previous article on "The Accuracy of Humidity Computations," Combustion, August 1934, page 15.

Compute the density of the mixture

$$d_m = d_a + d_v = 0.0676 + 0.0007 = 0.0683 \text{ lb per cu ft}$$

If the mixture density is the only result desired, equation (3) provides a means of computing it directly as soon as the vapor pressure is known.

$$d_a = \frac{B - 0.38\,p_v}{R_a T_d} = \frac{13.67 - 0.38 \times 0.21}{0.370 \times 538} = \frac{13.67 - 0.08}{0.370 \times 538}$$

$$= \frac{13.59}{0.370 \times 538} = 0.0683 \text{ lb/cu ft}$$

There are many cases in which the mixture density is all that is needed, and the possibility of computing this directly, without the necessity of working out air density and vapor density seems to be a useful saving of labor. As pointed out below, the accuracy of the result is limited by the usual accuracy in measuring the dry-bulb temperature, T_d, that is, the work is good to three significant digits.

The proposed method, it will be noted, yields just the results that the engineer needs to know, and nothing else. Once the vapor pressure has been computed, a single direct computation will give either the specific humidity, the air density, or the mixture density, without the necessity of computing any other results. If the relative humidity is desired, it is also computed directly as the ratio $p_v/p_d = 0.21/0.47 = 0.45$ or 45 per cent. If it be objected that this does not agree with the value 0.44 obtained by the older method, it may be replied that the discrepancy is equivalent to an error of less than 0.3 deg F in the wet-bulb temperature, so that it may be considered negligible unless temperatures have been measured with high precision.

When a single result is needed, the proposed method is much simpler and more direct than the older method. Even when all of the results are needed, the proposed method is considerably simpler than the other. The accuracy of the proposed method is better than the usual accuracy of the observations.

Example of the Second Type

Two atmospheres are to be mixed in proportions that are known or that are to be determined to yield a final mixture at a stated temperature. The humidity results are known for each initial atmosphere; in particular, the density of air and the specific humidity are known.

Atmosphere 1	Atmosphere 2
$t_d = 42$ F	$t_d = 75$ F
$t_w = 30$ F	$r = 0.55$
$B = 13.88$ lb/sq in.	$B = 13.88$ lb/sq in.
$p_v = 0.019$	$p_v = 0.24$
$d_a = 0.0746$	$d_a = 0.0689$
$s = 0.0009$	$s = 0.0109$
V = 2 cu ft	V = 5 cu ft

The total weight of air in each atmosphere, for the volumes given, is

$W_a = 0.1492$ $\qquad$ $W_a = 0.3445$

Likewise for the vapor

$W_v = 0.00013$ $\qquad$ $W_v = 0.00375$

In the final mixture, the weights of air and vapor will be the sums of the respective weights in atmospheres 1 and 2.

$W_a = 0.4937$ $\qquad$ $W_v = 0.00388$

The specific humidity of the final mixture will be the ratio of the vapor weight to the air weight

$$s = \frac{0.00388}{0.4937} = 0.0079$$

The barometric pressure is assumed to be unchanged. Usually it is the same for the original atmospheres and the final mixtures, but it might be different without affecting the method of computing.

The temperature of the final mixture may be known or unknown. If the final temperature is known, then the relative values of V_1 and V_2 are unknown. In this case, an easy method is to take $V_1 = 1$, and compute the necessary value of V_2. If the two initial volumes, V_1, V_2 are known, then the final temperature is unknown. In any case, the determination of the unknown quantity is by means of an equation asserting that the aggregate enthalpy (total-heat) of the final mixture equals the sum of the enthalpies of the two initial atmospheres. This computation is beyond the scope of this paper; it will be taken as completed. The temperature of the final mixture is 65 F.

Thus we know the specific humidity, the barometric pressure, and the dry-bulb temperature of the final mixture. We wish to find its relative humidity, its density or some other property of the mixture.

With suitable charts, the problem can be solved directly, usually with adequate accuracy; but if no chart is at hand, or if one is not familiar with the chart, resort must be hand to computation. The usual method is to assume a value of relative humidity or dew-point temperature, and compute the specific humidity. If this does not agree with the known value, another trial is made, and so on until the computed value checks the predetermined value. While this method is not unduly complicated, it tends to be somewhat tedious, especially if the computer is not good at guessing reasonably close.

The proposed method provides equation (2) whereby this step may be jumped at once. The vapor pressure is computed directly.

$$p_v = B \times \frac{1.61\,s}{1 + 1.61\,s} = 13.88 \times \frac{1.61 \times 0.0079}{1 + 1.61 \times 0.0079}$$

$$= 13.88 \times \frac{0.0127}{1.0127} = 0.17 \text{ lb/sq in.}$$

We now know, for the final mixture, the barometric pressure, the vapor pressure, the dry-bulb temperature and the specific humidity. It is a matter of simple and direct computing to find the relative humidity, dew-point temperature, densities or volume, as may be desired.

Derivation of the Specific Humidity Equations (1) and (2)

In any mixture of two ideal gases, Dalton's law assures us that each gas independently behaves according to the ideal gas equation of state. In other words, if we designate the two gases by the subscripts a and v,

$$p_a V = W_a R_a T \qquad p_v V = W_v R_v T \qquad (4)$$

In each case, p = partial pressure, V = total volume, W = weight of the constituent in the given volume, R = gas constant for the given constituent, and T = the absolute temperature (dry-bulb) of the mixture.

Now it is well known that the gas constant for an ideal gas is equal to the reciprocal of the molecular weight of that gas, multiplied by a constant that is the same for all gases. This is a direct consequence of Avogadro's law that equal volumes of gases under the same pressure and temperature contain equal numbers of molecules. In the common system of English units (p in lb per sq ft, V in cu ft, W in lb and T in deg F),

$$R = \frac{1544}{M} \qquad (5)$$

where M denotes the molecular weight of the gas.

Substituting this value in the foregoing equations, and dividing through by V, gives

$$p_a = \frac{W_a}{M_a} 1544 \frac{T}{V} \qquad p_v = \frac{W_v}{M_v} 1544 \frac{T}{V} \qquad (6)$$

If the pressures are not in pounds per square foot, the constant 1544 will be altered appropriately. For pressures in pounds per square inch, it becomes 10.72, and for pressures in inches of mercury (at 32 F), 21.83; whatever the units, the factor is a constant.

Dividing one of these equations by the other gives the ratio of the two partial pressures.

$$\frac{p_v}{p_a} = \frac{W_v}{W_a} \times \frac{M_a}{M_v} \qquad (7)$$

This relation holds for any mixture of substances that can properly be regarded as ideal gases. Air is one such substance, throughout the region of moderate pressures and temperatures. Water vapor may also be included in this group, but within narrower limits. Within the range of low pressures and moderate temperatures encountered in humidity computations, it has long been recognized that the vapor behaves as an ideal gas. For example, the ratio of actual vapor pressure to the pressure of saturated vapor at the same temperature is properly taken to be the same as the ratio of the corresponding densities. It is here proposed to extend the usefulness of this assumption.

To translate equation (7) into more familiar terms, let p_v denote the partial pressure of the vapor in the atmosphere. This is the actual vapor pressure, as found from psychrometric observations and computations, tables or charts. Then p_a will be the partial pressure of air in the atmosphere, which is equal to the total pressure, B, minus the vapor pressure, p_v. The ratio W_v/W_a is the weight of vapor per unit weight of air, and this is the quantity that is known as the specific humidity **s**. The final ratio is the ratio of the molecular weights of air and water, which is discussed below.

Equation (7) thus becomes

$$\frac{p_v}{B - p_v} = \mathbf{s} \frac{M_a}{M_v} \qquad (8)$$

Solving this equation for **s** and for p_v and substituting a numerical value for the ratio of molecular weights yields equations (1) and (2) stated at the beginning of this paper.

Value of Molecular Weight Ratio

What is the numerical value of the ratio of the molecular weights of air and water? Water, being a definite chemical compound, has a definite molecular weight, equal to 18.016, as may be confirmed by reference to any table of molecular weights. Air, being a mechanical mixture of numerous constituents, cannot have a definite molecular weight, but, since its composition is astonishingly constant all over the world and under various circumstances, it is possible to find the "equivalent" molecular weight of an imaginary gas that would have the mechanical properties of air. It may, for example, be computed by equation (5) from the gas constant for air, which is known with acceptable accuracy to be 53.34; this gives a value of 28.95 for the equivalent molecular weight[5].

Accepting these values, we compute the ratio of molecular weights as

$$\frac{M_a}{M_v} = \frac{28.95}{18.016} = 1.607 \qquad (9)$$

In equations (1) and (2), the value 1.61 has been used because an accuracy of the general order of magnitude of 1 in 100 is as good as can be claimed for specific humidity in the absence of unusual precision of observations; moreover, an accuracy of 1 in 100 is sufficient for all ordinary needs.

A Numerical Check

As a check on the dependability of this method of computing, the author has computed specific humidity values through a wide range, by the conventional method, and from each of them has computed the value N in the equation

$$\frac{p_v}{B - p_v} = \mathbf{s}N \qquad (10)$$

just as though N were an empirical constant.

Inasmuch as heating or cooling a mixture above its dew point does not alter its specific humidity, the easiest way to compute the specific humidity from vapor data is to compute it for the dew point temperature and the barometric pressure. The author has done this for dew points at each ten degrees F from zero to 100, and for each inch of barometer from 23 to 30. Vapor pressures and volumes were taken from the Keenan Steam Tables for temperatures above 32 F, and from the Smithsonian Meteorological Tables for lower temperatures. Most of the arithmetic was done by a computing machine. This gave 168 values of specific humidity. For each of them the value of N was computed. The individual values of N vary erratically. Above 32 deg F, the smallest value is 1.605, the largest is 1.608, and there is no discernible systematic variation. Below 32 F the

[5] Marks' Handbook, 3rd ed., page 319.

specific humidities are small and the limitation of significant digits gives rise to erratic variations. The value 1.599 occurs once. The next smallest value is 1.604, and the largest value is 1.614. The average of the values of N for the entire 168 points is 1.6067, which appears to be an acceptable check on the value 1.607 computed from the molecular weights.

It is therefore concluded that equations (1) and (2) may be used with confidence that they will give results that are as close to what may be regarded as the correct value as can be found with ordinary care in using the wet- and dry-bulb psychrometer. The reader has already been referred to a previous article in which this question of accuracy was discussed, where it was shown that to secure values of specific humidity varying by unity in the fourth decimal place, the dry-bulb temperature must be known to one-third of one degree, and the wet-bulb to one or two tenths of one degree. Equation (1) yields results that will not differ from those computed from vapor data by more than one unit in the fourth decimal place, and accordingly, it appears to be better than the thermometric precision that is usually attained.

Derivation of Equation (3) for Density of the Mixture

In fan testing and analogous work, it is necessary to compute the density of the atmosphere, that is, air plus vapor. The proposed method makes possible a further simplifiaction of this task, if this is the only result desired.

$$d_m = d_a + d_v \tag{11}$$

$$= d_a + d_a \times \mathbf{s} \tag{12}$$

$$= d_a(1 + \mathbf{s}) \tag{13}$$

$$= \frac{B - p_v}{RT_d}\left[1 + \frac{p_v}{1.61(B - p_v)}\right] \tag{14}$$

$$= \frac{B - p_v\left(1 - \frac{1}{1.61}\right)}{RT_d} \tag{15}$$

$$= \frac{B - 0.38\,p_v}{RT_d} \tag{16}$$

This equation, which is the same as equation (3), makes possible the computation of the mixture density without bothering with the intermediate values of air density, specific humidity and vapor density, which may be of no interest.

It is perhaps worth while to point out that, since p_v is always a small number, relatively low accuracy in determining it does not correspondingly lower the accuracy of the result. Since B may easily be measured to hundredths of an inch of mercury, the numerator may be reliable to four digits if p_v is determined to hundredths, that is, to two significant digits. The limit to the accuracy of the density will be in the measurement of the dry-bulb temperature, which will not ordinarily be closer than 1 in 1000, that is, half a degree. The density should not be carried beyond three significant digits unless the dry-bulb temperature is known with an error of about one-tenth of one degree Fahrenheit.

Conclusion

There is nothing new under the sun. This proposed method merely applies to the work of the engineer the method of attack that naturally occurs to the chemist. See, for example, "Principles of Chemical Engineering," by Walker, Lewis and McAdams, Chapter 14, where Grosvenor's system of computing is quoted from a paper published in 1908.[6] The method is, in brief, to carry out all computations on the weight basis. The method has much to commend it, but, unfortunately, it is set up in terms of a chart which is not widely accessible.

What the present proposal does is to facilitate computing on the weight basis, with the aid of the simple equations (1), (2) and (3) together with the ideal gas equation of state for air (the first of equations (4)).

The discussion of humidity relationships has been befogged by a special nomenclature and what often appears to be a tricky complexity of methods. This is unfortunate, for the situation is very simple. If we adopt the point of view that we are dealing with mixtures of two ideal gases, and if we employ the simple methods of computing on the weight basis, difficulties will dissolve. When water is evaporated or water vapor is condensed, the computations must be modified appropriately, whatever the method followed, and this is easily done when the weight basis is adhered to.

For the man who is working in this field continuously, charts based upon more elaborate equations are probably more convenient. For the worker with highly precise observed data more elaborate equations are indispensable. But for the engineer who has occasional need to compute humidity results, it is believed that the proposed simpler method will be much easier to handle. The equations involved are simple enough to be remembered, or they may be written on the fly-leaf of the Steam Tables for ready reference.

Summary of the Proposed Method

$$p_v = p_w - \frac{B}{30}\frac{(t_d - t_w)}{90}$$

Temperatures Fahrenheit
Pressures in any units

$$d_a = \frac{B - p_v}{RT_d}$$

R = 0.370 for pressures in lb per sq in.
= 0.754 for pressures in inches of mercury at 32 F

$$\mathbf{s} = \frac{p_v}{1.61(B - p_v)} \text{ and } p_v = B\left(\frac{1.61\,\mathbf{s}}{1 + 1.61\,\mathbf{s}}\right)$$

$$d_v = d_a \times \mathbf{s}$$

$$d_m = d_a + d_v = \frac{B - 0.38\,p_v}{RT_d}$$

$$\mathbf{r} = \frac{p_v}{p_d}$$

[6] Trans. Am. Inst. Chem. Eng., Vol. 1, 1908.

Edwin Jowett, vice-president in charge of power production of the Kansas City Power & Light Company, retired on October first after fifty years of active service in the utility field, the last sixteen of which were spent with that company. During this period he was in charge of the construction and extension of the Northeast Station and the Grand Avenue Station. He will continue in a consulting capacity with the company.

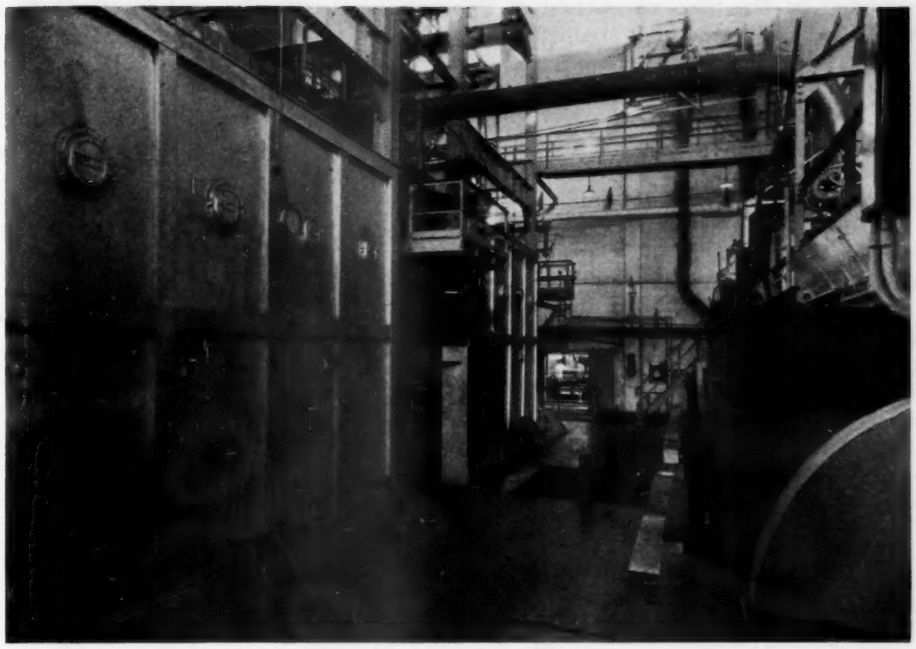

Fig. 1—Firing deck of inclined-grate hog-fuel furnaces showing boiler control panel at left and fuel feeders at right

Design and Operation of Hog Fuel Burning Equipment*

By HARRY S. BASTIAN
Engineer, Portland, Ore.

The growing scarcity of saw-mill waste and hog fuel on the Pacific Coast makes it more necessary to burn this fuel efficiently and thus increase the steam output for the quantity available and thereby save the cost of the more expensive supplementary coal or oil fuel which often becomes necessary for increased capacity. The author discusses the evolutionary development in burning this waste covering flat-grate, dutch-oven furnaces, water-cooled grates, inclined-grate furnaces with zoned combustion and the traveling grate. Combustion control, preheat and cinder arresting are also becoming important factors. Typical expected performances with the several types are mentioned.

THE evolution through which the fuel known as "saw-mill waste" or "hog fuel" is passing, is perhaps as revolutionary as that of any other branch of steam engineering. For years saw mills, at which this fuel originated, burned it in simple furnaces under equally simple boilers to produce their steam. Having more waste than they needed for this purpose, there was no thought of economy or regulation in its use. In fact, saw mills once regarded hog fuel in much the same light as early oil refineries regarded gasoline, namely, a by-product that was more or less a nuisance, to be disposed of as conveniently as possible. This evolution is marked by several clearly defined trends: First, the rapid strides made in the economics of hog-fuel usage, and its advancement to a scientifically controlled and technically supervised plane of usefulness; second, the fact that this process is keeping pace with that of other branches of steam engineering; and third, the fact that hog-fuel equipment is now being engineered on the basis of its own fuel characteristics and qualities, and not through a more or less perfunctory adaptation of analogous practices.

An actual scarcity of hog fuel, now felt by most pulp and paper mills, results in justifying expenditures to increase its burning efficiency out of proportion to the actual value of the fuel itself. Paper mills, as a rule, do not produce enough wood waste to supply their full fuel demands, and what they do supply does not have the best thermal quality for fuel. Consequently, those mills that are not able to secure enough purchased hog fuel to make up the deficiency must resort to coal or oil, which are more expensive. Obviously, if such mills can burn their available wood waste more efficiently, a corresponding saving will be made in the use of coal or

* Presented at the Annual Meeting of the Technical Association of the Pulp and Paper Industry, Portland, Oregon, Sept. 10, 1934.

oil, and the saving will be calculated on the basis of these more expensive fuels, not on the basis of the hog fuel saved. The problem, then, resolves not into burning less hog fuel for the steam output required, but to increase the steam output for the fuel burned. This indicates that the future trend of hog-fuel burning will be toward more efficient furnaces of moderate capacity rather than the extremely high capacity installation designed and built in the past.

In this development, efficient furnace design is receiving intensive study. For years the flat-grate, dutch-oven type of furnace has been accepted as the standard, and where high capacity and simplicity of operation are paramount requirements this type still maintains a dominant position. This is particularly true in paper-mill operation, where kiln-dried fuel is practically non-existant and fuel with high-moisture content must be used, for which class of fuel the dutch-oven furnace is well suited. All dutch-oven furnaces operate on the principle that the combustion of a highly volatile solid fuel, like hog fuel, is not a single process but is divided into three operations: first, preliminary drying; second, gasification of the volatile; and third, combustion of the fixed carbon and generated gases.

Functions and Limitations of the Flat-grate Dutch-oven Type of Furnaces

In the flat-grate, dutch-oven furnace all three operations take place concurrently, and the furnace must therefore provide facilities for simultaneously driving off the entrained moisture, gasifying the volatile matter and mixing it with the necessary air for combustion, and supporting the combustion of the fixed carbon. The furnace should and does act much as a gas producer, the gasification being promoted almost entirely by radiated and reflected heat from the furnace walls and roof. Securing a suitable reflecting action by the hot brick surfaces on the surface of the fuel, and securing a satisfactory mixture of combustible gas and air are the features that dictate the design of the furnace.

Fig. 2 shows a typical modern flat-grate, dutch-oven furnace. This is designed to burn an average grade of fir hog fuel with natural draft. A grate area of 1 sq ft to 42 sq ft of boiler heating surface was provided in this particular installation. With a dry fuel, a grate ratio of 1 to 50 could be used, and with wet fuel, containing about 50 per cent moisture, this ratio should be reduced to about 1 to 35. This latter ratio is also preferable where hemlock or spruce is used, even with a lower moisture content owing to its slower rate of gasification and combustion, and also to its being somewhat lower in volatile combustible. Note the drop arch at the rear, which is used to impart a sudden change in direction of flow of the gases leaving the furnace, creating a turbulence and consequently a more thorough mixture of gases and air. This is vitally necessary for effective combustion. The drop arch also provides a heat reflecting surface for the rear of the fuel pile that faces the open furnace throat. In this furnace the phenomena of drying, gasifying and burning all take place indiscriminately. Later a furnace is described in which these operations are separated into zones, promising a more efficient result. This type of furnace is often benefited by providing more refractory radiating surface, obtained by building a longitudinal center wall that divides the grate area and furnace into sections. The beneficial action of this additional radiating surface offsets that reduction in grate area by the amount occupied by the wall, with a net gain in furnace capacity. Very wide furnaces may have two or three of these division walls.

Although the temperatures produced by hog fuel in a dutch-oven furnace are not as high as those from other fuels, the action of the heat in the ashpit, generally quite intense, due to the burning fuel dropping through, is destructive to the cast-iron grate bars, and frequent renewals are required. This forms one of the most expensive items of hog-fuel furnace maintenance.

To eliminate these grate bar difficulties, water-cooled

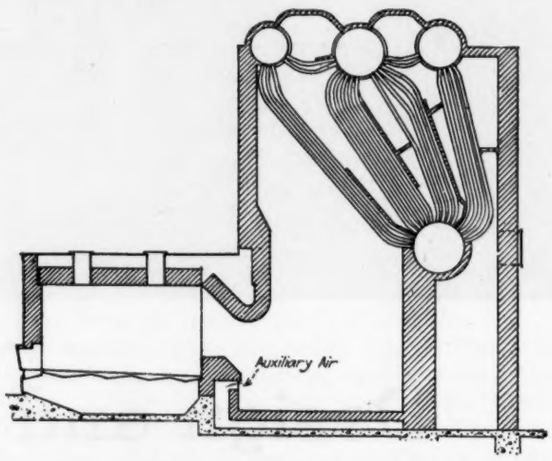

Fig. 2—Cross-section of typical wet-wood drop-nose arch flat-grate furnace

grates of several patterns have been developed. One form consists of small steel tubes welded to steel headers at the front and rear of the furnace. Water is circulated through these tubes from one header to the other. Some of these grates are in use in the boiler plant of the Weyerhauser Timber Company at Longview.

Another form of water-cooled grate consists of small steel channels placed edge to edge and welded to form a square tube. These tubes, in turn, are welded to similar channels, forming water-cooled grates. Some of these grates are in service in the plant of the Oregon Pulp & Paper Co. at Salem, Oregon.

Steel versus Cast-iron Water-cooled Grates

The steel water-cooled grates give satisfactory service so long as the water supply is not interrupted. They are susceptible to damage from overheating if the water supply should fail, and in some plants it has been found advisable to install signal systems to give warning when the water supply is interrupted. A new form of cast-iron, water-cooled grates has been developed to eliminate this danger. These grates are cast in hollow sections from a heat-resisting nickel-chrome alloy, so designed that the water circulates in series through the sections from one end of the furnace to the other. A set of these grates for a small hog-fuel furnace is shown in Fig. 3. These grates are in use in furnaces at the plant of the Columbia River Paper Mills in Vancouver, Washington. All practical types of water-cooled grates well justify their cost since their life is many times that of the cast-bar grate, while the initial cost need not be much more. They render unnecessary the use of water in the ash-pits and permit the use of preheated

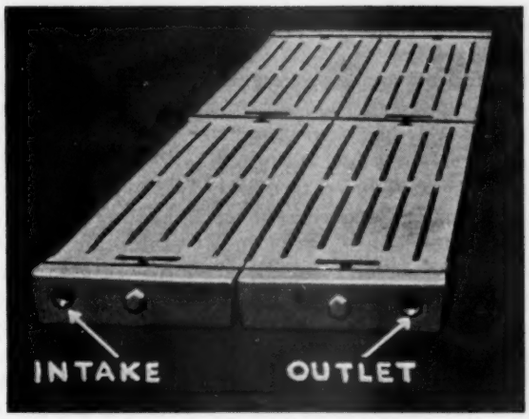

Fig. 3—Water-cooled grates

air at high temperatures. Perhaps the most noticeable feature of their use is that they are non-slagging.

With the increasing economic importance of hog-fuel utilization, the matter of more efficient furnace design is receiving intensive study. The flat-grate furnace has been brought to a high state of perfection so far as quantity of output is concerned, and it is probably safe to say that this furnace in its present state is abreast of the times in its ability to carry a high sustained output with all classes of fuel. However, the demand for the highest possible furnace efficiency has disclosed some shortcomings in this furnace which later designs are endeavoring to correct. The flat-grate furnace is not well adapted to close regulation of air admission in conformity with changing load conditions. The best that can be done is to admit enough air to keep smoke at a minimum and burn enough fuel to furnish all the steam required. The obligation of efficiency is felt to be fulfilled if a fair percentage of CO_2 is produced with smokeless combustion, and further improvements in efficiency are generally sought by the use of water-cooled furnace walls, air preheaters, etc., with the furnace being left more or less out of the question.

Water Vapor Detrimental

The flat-grate dutch-oven furnace has another noticeable disadvantage. Steam from the moist fuel comprises a considerable percentage of the gases originating in the furnace. This water vapor or gas is nearly 50 per cent lighter than the other gases being generated, with the exception of methane, and will quickly leave the furnace if means of exit are provided. Since it has the capacity to absorb heat at about twice the rate of the combustible gases, its presence in the furnace is decidedly detrimental. However, it is necessary to obtain a thorough mixture of volatile combustible and air, and the means used to obtain this mixture in the flat-grate furnace also results in mixing the water vapor quite thoroughly with the burning gases, and undoubtedly results in lowering the furnace temperature. If some means were provided to permit this water vapor to escape without passing and mixing so thoroughly through the zone of combustion a more efficient furnace action should be obtained.

In line with the quest for more efficient hog-fuel furnaces, it may not be amiss, to direct attention briefly to some of the principles being employed to burn highly volatile wet fuels in other countries, and to indicate what results are being obtained in our own vicinity from the application of these principles.

European Practice with Zoned Combustion

Modern European practice in burning wood waste and analogous fuels is principally based on the recognized fact that the combustible matter is largely volatile and will burn as a gas. For that reason the best known of these furnaces have their designs based on their action as a gas producer as much as that of a combustion furnace. Typical examples are the Bergmans furnace in Germany and the Malm furnace in Sweden. Their design stresses the principle of furnace operation mentioned, namely that the combustion of a highly volatile solid fuel is not a single process but is divided into preliminary drying, gasification of the volatile and combustion of the fixed carbon and generated gases. The chief point of difference from the ordinary dutch-oven furnace is that these furnaces are so designed that some or all of the processes are carried out in separate zones at temperatures most suitable for them. The lowest temperatures are found at the fuel inlets where the moisture is first driven off. In the second stage or zone the temperature rises and the volatile hydrocarbons are volatilized. In the last zone the fixed carbon and volatile gases burn.

Efficiencies of boiler, superheater and the Bergmans furnace up to 75 per cent is claimed, when using fuel of 43 per cent moisture, 0.6 per cent ash and a fuel value of 5470 Btu per lb. This furnace provides definite means for the escape of water vapor without its mixing with the burning gases.

An installation of the Malm "half-gas" furnace was described in January 1934 issue of COMBUSTION. This furnace approaches more nearly the designs that have been developed in this country. The zoning is not sharply defined, being merely theoretical divisions of a single combustion chamber, although their functions are separately conducted and not intermingled as in a flat-grate furnace.

The foregoing types of inclined-grate furnaces illustrate applications of the principles of zoned combustion, which are being utilized to some extent in local practice. One of the first successful installations of the inclined-grate, dutch-oven furnace was at the plant of the Everett Pulp and Paper Company, which gave satisfactory service. Owing to a lack of understanding of the principles underlying this type, several other inclined-grate furnaces were installed which were little more than tilted flat-grate, dutch-oven furnaces. Naturally they did not evidence any particular improvement in operation, and since they were more expensive to build, they did not become popular. Other installations were made where the class of fuel was not suitable for the furnace. A number of these installations were later taken out. These instances are cited to point out the fact that modern hog-fuel burning equipment must be an engineered product based specifically on the characteristics of the fuel, and not on an offhand adaptation of something similar. This is further illustrated by the fact that more carefully engineered designs of the inclined-grate furnace have again proved this type to be satisfactory.

Combustion control is becoming increasingly important, as the advance to higher efficiencies goes on. With

the flat-grate dutch-oven furnace about all that can be done to increase ratings is to open the doors over the fire and increase the air flow to the point where the smoke stops. It is to the credit of the furnace that this operation is generally accompanied by an increase in output and a fair percentage of CO_2. However, positive and graduated control is not always obtained and the operator accepts whatever efficiency that happens to result therefrom when he has the rating he wants. A balanced furnace draft under these conditions is unattainable. Experience with inclined-grate furnaces has indicated that better combustion control can be obtained with lower draft velocities and less excess air than is the case with the flat-grate furnaces. The Malm furnace and the operating data on the Portland Woolen Mill furnace, illustrate the facility with which good ratings and efficiencies can be obtained with low draft pressures and positive draft control. Generally the efficiency of the system drops because of the increase in the draft pressure or velocity, and there results a more or less definite relation between the rate of increase of combustion and the rate of increase in the draft. The point to be noted is that the rate of combustion can be increased more rapidly in relation to the draft with the inclined-grate furnace than with the flat-grate furnace, even though the latter will provide the higher capacities. This incidentally provides excellent means for smoke control.

Other users have found that the inclined-grate furnace lends itself well to instrument control of combustion. The Camas plant of the Crown Willamette Paper Company, which operates a satisfactory installation of inclined-grate furnaces offers a good example of controlled hog-fuel combustion. At this plant, instrument control of the furnaces is comparable to that in plants using other fuel, showing that a hog-fuel furnace can be designed and operated at the same high grade as that for other fuels. A view of the firing deck of these furnaces is shown in Fig. 1.

In California some investigations are being conducted as to the effect of reduced draft pressures on furnace efficiencies. It has been found that in some cases where comparatively dry fuel is burned, an original stack draft of 1 in. can be reduced to 0.35 in. without affecting the furnace capacity and the efficiency has been improved. The engineers state that these results are obtained through positive and complete control of the furnace draft and temperature, and by allowing the generated furnace gases to push themselves out of the furnace instead of being pulled out with the stack draft.

These plants make use of a novel draft regulator which, like the present inclined-grate furnaces, is an old idea originally used with little success, but rendered successful through more correct understanding and better engineered application of its operating characteristics. Fig. 4 shows a typical cross-section of this device, which is installed near the top of existing stacks. The return bend discharges the gases downward against the surface of water carried in a conical tank, the operator controlling the draft by raising and lowering this water level. This device is in use on several plants burning wood waste, and one is just going into service on a plant in Greenville, Cal., designed to burn green sugar pine sawdust with a high-moisture content. Operating records from one plant using this device with fairly dry wood fuel, show that smoke can be almost instantly controlled with it, and, furthermore, that after it was installed, the improvement in furnace efficiency due to better draft regulation enabled the plant to increase its steam output over 25 per cent with the same fuel.

In modern steam plant economics the air preheater is a factor of growing importance. An air preheater requires forced draft. The inclined-grate furnace lends

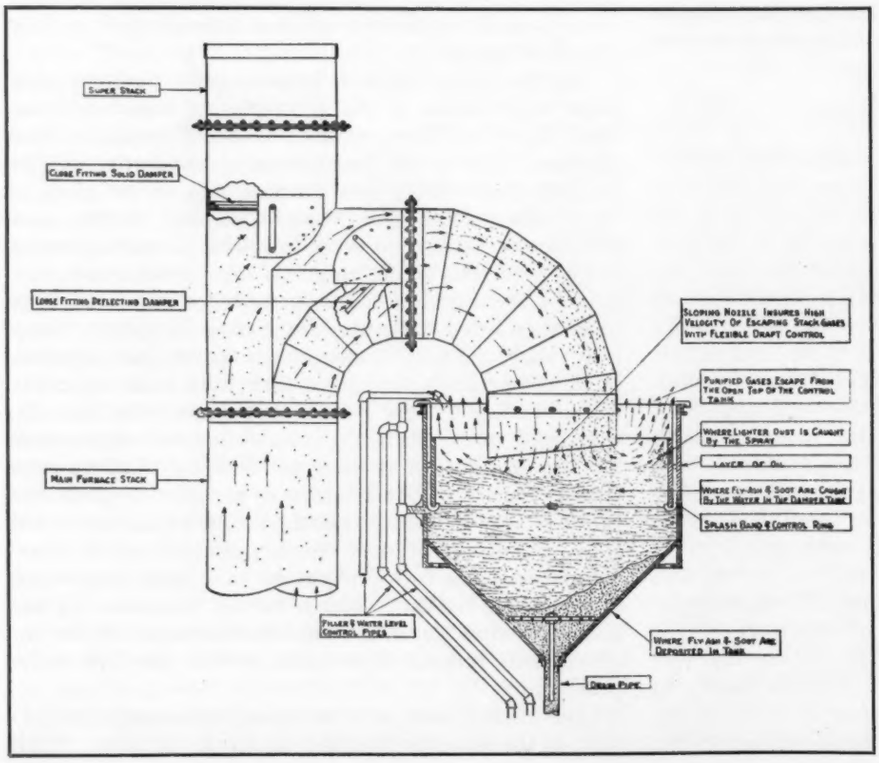
Super Stack
Close Fitting Solid Damper
Loose Fitting Deflecting Damper
Main Furnace Stack
Sloping Nozzle Insures High Velocity Of Escaping Stack Gases With Flexible Draft Control
Purified Gases Escape From The Open Top Of The Control Tank
Where Lighter Dust Is Caught By The Spray
Layer Of Oil
Where Fly-Ash & Soot Are Caught By The Water In The Damper Tank
Splash Band & Control Ring
Filler & Water Level Control Pipes
Where Fly Ash & Soot Are Deposited In Tank
Drain Pipe

Fig. 4—Martin draft regulator in which the gases discharge downward over water in the conical tank. The draft is controlled by raising or lowering this water level

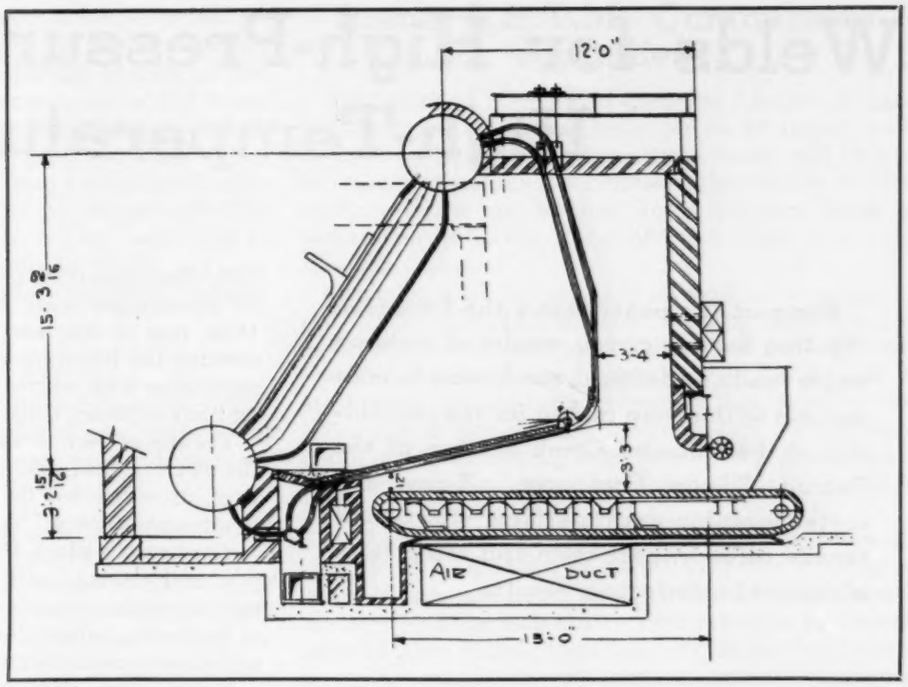

Fig. 5.—Cross - section of stoker furnace for burning hog fuel as designed for a lumber mill in the Northwest

itself to the use of forced draft more satisfactorily than does the flat-grate furnace. Some plants using preheated air with flat grates require complicated furnace construction to deliver the air over the fire, an indispensable requirement of the flat-grate furnace. The inclined-grate furnace does not require this expedient to adapt itself to the use of forced draft. In Europe, where the wood-fired gas producer is in wide use, some authorities state the inclined-grate producer will work satisfactorily only with forced draft.

One of the principal points of difference between flat-grate and inclined-grate furnaces is in their maximum capacities. The inclined-grate furnace does not have the ability to carry extreme overloads that the flat-grate furnace has. However, keeping in mind that our developments are affected by a deficiency of hog-fuel supply, it is fairly conclusive that increased efficiency is of more importance than increased capacity. It does not seem to be good engineering to design a boiler plant with hog-fuel furnaces to give 300 or 400 per cent rating, when the available hog-fuel supply may be sufficient for only 200 per cent continuous rating with the balance to be made up with oil. A better plan would be to build a furnace that would give the greatest possible output under continuous operation at about 200 per cent rating, rather than one that could operate at 300 per cent rating, doing this part of the time and perhaps 100 per cent rating the rest of the time.

The question has often arisen as to whether or not hog fuel can be successfully and economically burned on a mechanical stoker. This has been given much study and although, to the author's knowledge, no actual installations of stokers primarily for hog fuel have been made, the results of this study to date may be of interest. It is the consensus of opinion of those considering the problem that a traveling grate stoker is the most practical machine for burning hog fuel. A new type of traveling grate stoker furnace has recently been developed and used successfully in a number of installations for burning fuels of low heating value and high-moisture content (over 40 per cent), and the designing engineers are practically unanimous in their opinion that it will function equally well with hog fuel. One reason for this opinion is that the fuel in question, low-grade lignite, was formerly burned on flat grates in a dutch oven, much like a hog-fuel dutch oven, and the results were similar to those obtained with hog fuel in similar furnaces.

The question of fuel carry-over naturally brings up a subject of considerable importance to pulp and paper mill operators—that of cinder elimination. There are three recognized methods of cinder elimination in use in the Pacific Coast area, first, the commonly known cyclone cinder collector, second, the more expensive cinder washer and third, the return-bend collector. The cyclone collector is effective, but it requires an induced-draft fan which by the high velocities it sets up often draws from the furnace a plentiful supply of cinders. However it is comparatively inexpensive to install and where mechanical draft is to be used anyway, say with an air preheater installation, it is probably the most satisfactory cinder trap available. The cinder washer is built like a modified air washer, and while it is no doubt effective, it requires mechanical draft, and is more expensive to operate if the water must be pumped. It does remove smoke from the gases which the cyclone collector does not do. A cinder washer has been in service for some years at the Oregon Pulp and Paper plant at Salem and is reported to be giving satisfactory results. The return-bend collector is the only device of this kind known to the author that operates with natural draft. This, unlike the others, cuts down the carry-over from the furnace by reducing the furnace draft velocity a small amount. This collector is in service at several plants in California, but none have so far been installed in the Pacific Northwest. So far, with the exception of the plant under construction at Greenville, Cal., its use has been confined to plants burning dry shavings and waste. This fuel, often by its light nature, produces more cinders than wet hog fuel.

Welds for High-Pressure, High-Temperature Piping

Abstract of a paper before the American Welding Society giving results of tests on welds made under field conditions in connection with steam piping for the rebuilding of the Connors Creek Station of the Detroit Edison Company. X-ray and metallographic examinations, short-time tensile tests, impact tests and creep tests all showed satisfactory results.

AT the Fall Meeting of the American Welding Society, held in New York, October 1 to 5 a paper by A. E. White, D. H. Covey and C. L. Clark described an examination of welds made under field conditions for high-pressure, high-temperature piping. These tests were made in connection with the rebuilding of the Connors Creek Station of the Detroit Edison Company to permit operation of the new section at 650 lb and 850 F, the plant having been built originally for 225 lb and 650 F steam temperature.

Fusion welding, by the direct-current, metallic-arc process, is being employed for main and auxiliary superheated steam piping for the above mentioned steam conditions and for boiler feed piping which operates at 1000 lb per sq in. pressure and 385 F. The main superheated steam piping is especially noteworthy in that there are no flanged joints between the superheater outlet header and the inlet end of the turbine stop valve, all valves except the turbine stop valve being of the welding-end type.

The decision to adopt fusion welding to the extent indicated was arrived at only after extensive investigations had indicated that sound reliable welds could be produced under field conditions by welders employed by the Company's Construction Bureau. Preliminary tests were directed toward determining the most satisfactory form of bevel, the proper clearance, proper electrode sizes and the effect of such operations as peening and stress-relieving. Following these tests, two welds were made under conditions duplicating field operations and submitted to the Department of Engineering Research of the University of Michigan for various destructive tests.

These two samples involved a pipe-to-pipe weld and a pipe-to-casting weld, the latter because it was proposed to use welding-end valves. The pipe used was 16-in. seamless steel pipe with the following analysis: carbon 0.33, manganese 0.75, silicon 0.06, aluminum (metallic) 0.04, chromium 0.06, phosphorus 0.01 and sulphur 0.02; all percentages being by weight. The casting was a 16-in. ring of the same wall thickness as the pipe and showing the following analysis by weight: carbon 0.24, manganese 0.62, silicon 0.36, chromium 0.82, nickel 1.19 and molybdenum 0.40.

The pieces were so assembled as to require welding in the flat, vertical and overhead positions. The welds were stress-relieved by heating with electric induction to a temperature of 1100 F for one hour.

The tests to which the welded as well as the original pipe and castings were subjected, included X-ray and metallographic examination, tensile and impact tests at both room temperature and 850 F, creep tests at 850 F and temper-embrittlement tests.

X-ray examination of the pipe-to-pipe weld showed 60 per cent of the circumference entirely free from defects, as was 25 per cent of the pipe-to-casting weld. The degree of porosity observed in the remaining sections of these welds was considerably less than the maximum allowed by the A.S.M.E. Boiler Code for Class 1 fusion welding.

The photomicrographs showed the original pipe to possess a somewhat coarser grain than is sometimes found in pipe material, but the structure of the weld proper was exceedingly fine grained.

Physical tests on the welded pipe-to-pipe specimens and on the welded casting-to-pipe specimens were both found satisfactory. They showed good tensile strength, good yield stress, good proportional limit values and excellent ductility. In only one test was the ductility, as measured by the per cent elongation, low and in only three tests was the reduction of area not up to what it should be. In two of the specimens from which these values were obtained there was evidence of slight porosity which would account for the low ductility values.

Impact tests were made at 80 F and 850 F on the original pipe and casting material as well as on the welded specimens. While satisfactory, the test at 850 F showed impact values for the pipe material and the welded specimens to be considerably under those obtained at 80 F. This was to be expected and was probably due to the fact that at this temperature the metal shows its lowest, or approaches its lowest, resistance to impact. Even at this temperature the material possesses a sufficient degree of impact resistance to render it satisfactory for the majority of commercial operations.

Creep tests were made on the original pipe, pipe-to-pipe and casting-to-pipe specimens at 850 F. The loads employed were 7000, 10,500, 12,000 and 15,000 lb per sq in. In practically all cases, except under a stress of 12,000 and 15,000 lb, the specimens showed little, if any, creep and little creep was shown at 12,000 lb. The values obtained showed that the materials have a satisfactory resistance to creep for the purpose intended.

The short-time test was conducted by heating impact

specimens of the various materials at 850 F for half an hour and then air-cooling one lot and water-quenching the other; also by taking additional specimens and heating them for 48 hr at the temperature of 850 F and then air-cooling one set and water-quenching the other. If the samples which are water-quenched show values decidedly under those obtained from air-cooling the material is considered to be subject to temper-embrittlement. In all cases, the drop in impact value due to water-quenching was not sufficient to justify any conclusion that these materials were subject to temper-embrittlement.

Conclusions

On the basis of the results obtained from the metallurgical examination of the proposed pipe material for the main steam lines of the Connors Creek Station, the following conclusions may be drawn:

1. The X-ray examination showed that the welded sections were of a satisfactory quality.
2. The metallographic examination of the welded pipe-to-pipe and the welded casting-to-pipe sections showed the welds to be of an excellent type. The grain size was unusually fine in the welded sections, due doubtless to the method of welding employed.
3. The short-time tensile tests at room temperature and 850 F showed all of the materials to possess a suitable combination of strength and ductility. The results obtained from the welded specimens were surprisingly good.
4. The impact values for all the materials tested were satisfactory.
5. The creep tests indicated the original pipe material as well as the welds to possess a sufficient resistance to creep. In fact, even under a stress of 15,000 lb, an elongation of but from 1.1 to 1.5% would be expected in 100,000 hr.
6. The temper-embrittlement tests may be said to be negative.

In conclusion, it is believed that the plain-carbon steel of the type tested and the Alloy H castings will render satisfactory service under the proposed operating conditions. These materials can be satisfactorily welded so as to produce the desired continuity of service without introducing operating hazards. This statement is made, of course, on the assumption that all the materials will be carefully inspected during production and installation.

To Enforce Licensing Law

At a meeting held at Albany on September 28, six professional engineers, named by the New York State Society of Professional Engineers were appointed by the State Department of Education to serve as special investigators in the enforcement of the Engineers' Licensing Law. Their duties will be to investigate any reported violations of Article 55 of the education law, which regulates the practice of professional engineering and which declares it unlawful to practice engineering or to use the designation engineer without a professional engineer's license.

Some A.S.T.M. Committees Activities

The Standard Methods of Chemical Analysis of Carbon Steel and of Alloy Steels are to be revised and brought up to date. An important change will be the inclusion in these revised methods of procedures for the analysis of cast and wrought irons, this work being in cooperation with the Committees on Cast Iron and Wrought Iron.

Committee A-1 has as one of its most active projects, the development of standards covering materials for high-temperature service. Alloy-steel castings and seamless alloy-steel pipe for service from 750 to 1100 F are covered in tentative specifications just issued by the Society, and requirements for alloy-steel bolting, nuts and forgings are nearing completion. A proposed standard for carbon-steel nuts for steam service up to 850 F will be submitted shortly.

A Section on High-Temperature Data proposes to compile creep data for available materials covering a range of temperatures from 750 to 1100 F which would fix their load-carrying ability with reference to various rates of creep ranging from one per cent in 10,000 hours to one per cent in 100,000 hours, the rate of creep being taken as that obtained over the period extending from the 700th hour to the 1000th hour of duration of the test.

The committee will continue studies of heat-checking of steel dies and plans to conduct tests to determine the effect of repeated heating of the surface of steels followed by drastic cooling after each heating period at temperatures approximating those which are attained by dies during operation in casting practice.

Committee on Coal and Coke

A number of projects confront the A.S.T.M. committee working on coal and coke. An agglutinating value test for coal has been published for information and while this method shows satisfactory check results in the same laboratory, there has been some lack of agreement between different laboratories. The causes for this are to be studied.

Experimental work is under way to develop an adequate method for determining slacking properties of coal, that is, a method to measure disintegration when exposed to the weather. Investigations on accuracy of various methods of sampling coal will be carried out. In view of the expense involved in conducting coal sampling experiments, it is extremely difficult to obtain the data required to determine the most economical method of sampling coals containing different amounts of impurities and differing in size. By economical is meant the smallest gross sample that may be taken to get a sample within a predetermined degree of accuracy.

Coal grindability tests are being made at six different laboratories, using four laboratory methods, on a series of five coals varying from a friable semi-bituminous coal to a hard anthracite. The purpose of this work is to determine which of these methods is best adapted to measure the grindability of coal in connection with commercial pulverization of coal for powdered coal installations. The committee hopes to draft methods of testing coal to determine resistance to breakage on handling.

Notes on Piping and Valves

The recent Prime Movers Report on "Station Piping" reviews central-station practice in the use of welded pipe, pipe joints for high-pressure and high-temperature service, valve trim for such service, corrosion and deposits in piping and piping troubles during low-load operation of plants. The original report, of which this is an abstract, contains tables giving in detail the materials used and the methods of fabrication and erection employed for piping for various service conditions by a large number of operating companies.

THAT welded piping is now used quite generally for all types of service in central stations is shown by the recent Prime Movers Committee on "Station Piping." The greatest number of installations have been made for superheated steam lines, with boiler feed lines and fuel-oil systems next in order. The maximum pressures reported on welded jobs are 730 lb per sq in. for steam and 900 lb for boiler feed. The maximum temperatures are 860 F for steam and 960 F for mercury vapor.

Both oxy-acetylene and electric-arc welding are used, the former being preferred by some companies for trench or tunnel work or in confined locations, for welding thin sections, and for piping less than 6 in. The latter seems to be preferred for plate work and larger pipe.

The butt type of weld with a 90-deg V (or 45-deg bevel on each pipe end) is most generally used, although some companies report satisfactory results with a 60-deg V and also a V-shaped groove for large heavy pipe.

Stress relieving of welds made in the field has been employed in many installations, but is not universal practice.

Some companies appear to regard with hesitation the welding of large valves in pipe lines, although this has been done in some instances. No x-ray inspection of field welds is reported, but for shop welds this method is often used especially where required by the Boiler Code. In addition to visual inspection many companies test the welds by hammering while the pipe is under hydrostatic test.

Pipe Joints for High-Pressure and High-Temperature Service

The operating experiences by member companies indicate that Sargol and Surlun welded type joints continue to give satisfactory service for a wide range of pressures. Joints requiring frequent breaking are not welded. When joints that have been welded are opened, resurfacing is often necessary and the joints are not rewelded. For both cases satisfactory results have been obtained with gaskets made of soft iron, corrugated stainless steel and annealed copper. Tongue-and-groove joints are not as widely used, but satisfactory operation is reported in practically all cases.

Van Stone joints for service at 400 lb per sq in., 750 F have given satisfaction in many installations or can be made satisfactory with the use of proper gasket material. No extensive use of the ring-type joint is reported.

Valve Trim

Stainless-steel valve trim has given satisfactory service in several installations with temperatures as high as 860 F. Some reports indicate a tendency for stainless steel to seize if one part is moved relative to the other when in contact. Several companies report trouble with corrosion and cracks in valve stems made of stainless steel with 12 to 14 per cent chromium.

Difficulties are reported in some cases with nitralloy valve trim above 750 F, while other users have found it entirely satisfactory. For service at temperatures at 750 F and below, and in combination with other materials for valve seats, nitralloy trim appears to give general satisfaction. However, some trouble has occurred with nitralloy because of brittleness and failure to resist bending or twisting.

The use of monel metal appears to be confined generally to temperatures under 700 F, while stellite facings are reported to have shown good results by two companies.

Welded Plate Pipe

Satisfactory experiences are reported in the use of large size pipe made from steel plate, bent and welded. Three companies are using such pipe for condenser circulating water and others are using this type of piping for atmospheric-relief lines. Installations for steam service at 750 F are reported by three companies, one for 24-in. pipe, one inch thick, for 400 lb per sq in. pressure, another for 24-in. pipe under 360 lb per sq in. pressure, and the third for 32- and 36-in. reheat steam piping at 100 lb per sq in. pressure. The use of welded plate pipe for large receiver pipes and certain heat exchangers is also reported.

Corrosion and Deposits

Some trouble from corrosion of piping in boiler feed lines is reported and in two instances improvement was effected through a reduction of the oxygen content of the water. In none of the cases reported was the trouble serious. Reports received from companies which have had trouble with scaling of turbine blades indicate that seven have not had deposits form in steam lines while four have had such deposits.

With regard to corrosion of underground blow-off lines, three companies report satisfactory experience with

cast-iron piping, while one company states that underground lines have been found bad and had to be abandoned. Steel pipe has given trouble for such service, according to two companies. In one case the steel pipe, with screwed joints, was laid partly in sandy soil and partly in cinder fill. In the other case, the steel section of a steel and cast-iron blow-off line, laid in ash fill, failed after four years' service, while the cast-iron section was found to be still in good condition. Transite pipe has been used successfully by one company for part of an underground salt-water line which was below river level. This part of the line was originally of cast iron which had become soft and graphitic. Cement-lined pipe has received some attention for underground service, but no extensive installations have been made for station use.

Troubles During Low-Load Operation

Piping troubles in steam lines accentuated by the temperature changes prevailing with low-load operation are reported by nine companies. Condensation, lack of circulation, use of carbon-steel bolting, and insufficient provision for expansion are some of the reasons given for the trouble. In several instances, the difficulty has been overcome by using different gasket material, tightening bolts and changing to necked bolts or alloy-steel studs.

Two companies report that trouble of this nature with Van Stone joints for steam lines at 200 to 265 lb per sq in. pressure has been eliminated by the use of corrugated monel metal gaskets covered with "Smooth-on composition" and copper gaskets were found to be unsuitable.

When turbines are temporarily shut down, but must be kept available for service at relatively short notice, the throttle valves frequently do not completely shut off steam to the turbine. One company reports that this difficulty has been overcome by installing, directly ahead of the throttle valve, a solid wedge-gate valve which remains tight. Another company states that it has found no method of stopping leaks between bodies and screwed-in seats of throttle valves, but that bolted seats do not present this difficulty. It is the practice of another company to provide each turbine steam lead with a free-blow valve between the throttle valve and the shut-off gate at the header. The free-blow valve is kept open at all times when the turbine is shut down, thus preventing leakage into an idle turbine. Still another company reports that the most successful method of keeping throttle valves tight is to grind in the seats when they are hot.

Commenting upon stud failures, one of the member companies, the Houston Lighting & Power Company, says:

"The studies made in connection with the stud failures reported show the need of a comprehensive specification for stud and bolting materials for use in high-temperature services. It is considered that the impact resistance of the material is an important property and should have a prominent place in any specification. It is felt that data giving impact resistance (at room and at operating temperature) of studs in service and of similar unused studs, would be of benefit to operators and designers."

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REVIEW OF NEW BOOKS

Any of the books reviewed on this page may be secured from Combustion Publishing Company, Inc., 200 Madison Ave., New York

Industrial Furnaces (Third Edition)

Volume I

By W. Trinks

A thorough and up-to-date revision of this important technical treatise has just been published. Research data are now available on points for which, in former editions, no material was at hand save the author's own experience, and these data, of course, are included in the current edition.

Volume I treats of the practical aspects of design and operation, the subject matter being divided into sections on the capacity, the economy, the thermal efficiency, the strength and durability and the movement of gases in furnaces. Appendices discuss in detail some of the most recent developments in the field of industrial heat. A large number of graphic illustrations, as well as numerous typical examples, reinforce the text.

The author is professor of mechanical engineering at Carnegie Institute of Technology, a heat-utilization consultant of world-wide reputation, and a leading authority on industrial furnace design and construction. Professor Trinks does not offer untried theories; the conclusions he presents have been tested and proved in actual furnace practice.

This book contains 456 pages, size 6 × 9, including a comprehensive index. Price $6.00.

Boiler Feed and Boiler Water Softening

A Boiler Operators' Manual

By H. K. Blanning and A. D. Rich

Boiler Feed and Boiler Water Softening is a practical treatise on the subject of the analysis of water and its treatment, and outlines clearly the method by which owners and operators of steam plants can make analyses, interpret the analyses and treat to suit each individual case.

This book was written by practical operating men and was intended for the average operating engineer and not the trained specialist. Accordingly, the authors have tried to eliminate as much as possible of the "heavy chemistry" in preparing this material.

In this volume the authors cover a limited field of water treatment, namely, that referring to boilers. No attempt is made to touch even slightly on water treatment for potability, clarifying or partial softening for city supplies.

The scope of this book, as indicated by the chapter headings, is as follows: Equipment for Making Plant Water Tests; Preparation and Standardization of Water Testing Reagents; Sampling Water for Tests; Methods of Making Field or Plant Water Tests; Special Laboratory Water Tests; Symbols for Interpreting Water Tests; Interpretation of Raw Water Titration Tests; Specifications for Water Treating Chemicals; Instructions for Internal Treatment; Directions for External Treatment; Interpretation of External Treatment Results; Internal Treatment Control; Scale Prevention by Carbonate-Sulphate Relation; Caustic Embrittlement of Boiler Plant; Coagulation; Zeolite Softening; Filtration; Boiler Scale Formation; Corrosion; Water Softening Chemical Equations; Chemical Equivalent Weights; Common Names for Chemical Compounds; Miscellaneous Notes.

The book contains 156 pages, size $8^1/_2 \times 11$ and many valuable charts. Price $3.00.

Transactions A.I.M.M.E.

Coal Division—1934

This volume covers papers presented at the Coal Division meetings of the American Institute of Mining and Metallurgical Engineers at Hazleton, Pa., Columbus, Ohio and at the 1933 and 1934 Annual Meetings of the Institute in New York. Included are papers on coal mining, preparation, classification, evaluation of coal for coke, coal utilization, coal land valuation and economics of the industry.

Of special interest to power men are papers on "Use Classification of Coal for Stationary Steam Generation" by T. W. Harris; "Classification of Coals of the United States According to Fixed Carbon and B.t.u." by W. A. Selvig, W. H. Ode and A. C. Fieldner; "Estimation of the Grindability of Coal" by H. F. Yancey, O. L. Furse and R. A. Blackburn; and "Competitive Relation of Coal and Petroleum in the United States" by W. S. Hutchinson and A. J. Breitenstein. Discussions in all cases are included.

The volume contains 495 pages, 6 × 9 in., and is bound in cloth. Price $5.00.

American Inventors

By C. J. Hylander

Brief, entertaining sketches of the lives of nineteen well-known American inventors are contained in this book, which, although intended primarily for boys of a mechanical turn of mind, gives much information that is of interest and value to the maturer mind, particularly from a reference standpoint.

Among the inventors whose stories are told are Benjamin Franklin, John Fitch, Eli Whitney, Robert Fulton, Samuel F. B. Morse, John Ericsson, Charles Goodyear, Alexander Graham Bell, Thomas Alva Edison and Lee de Forest.

This book contains 216 pages, size $5^1/_2 \times 8$, including illustrations and portraits of the inventors. Price $2.00.

STEAM ENGINEERING ABROAD

As reported in the foreign technical press

Combination Isolating and Safety Valve

Engineering (London) of September 7 describes a combination valve for application and protection to vessels supplied with low-pressure steam through a reducing valve from a high-pressure system. The new valve, made by W. H. Bailey & Co., Salford, Manchester, Eng., has two chambers, one above the other. In the upper chamber is located the safety valve which is of the high-lift type. This connects with the supply pipe to the low-pressure vessel. Its spindle projects into the lower chamber and carries the stem of the isolating valve. The spacing is such that when one valve is closed the other is open. In normal operation the isolating valve is open and the safety valve closed. If excess pressure occurs at the inlet, from failure of the reducing valve or accidental admission of high-pressure steam, the safety valve immediately opens and pulls the isolating valve to its seat. Conversely, should a pipe or vessel on the low-pressure side rupture under normal pressure, the resultant sudden increase in velocity and volume of the steam shuts the isolating valve and at the same time opens the safety valve.

Condenser Research

"Some Factors in the Design of Surface Condensers" is the subject of a paper by H. L. Guy and E. V. Vinstanley before the Institution of Mechanical Engineers (England) and reprinted in the August issue of the *Metropolitan Vickers Gazette*.

The increasing size of surface condensers has necessitated a reconsideration of the accepted methods of approach to condenser design. In a number of cases noted, the apparent rate of heat transmission appeared to be lower and the actual vacuums $^1/_4$ to $^3/_4$ in. less than had been anticipated. Inasmuch as $^1/_2$ in. of vacuum in the range between 28 and 29 in. makes a difference of $2^1/_2$ to 3 per cent in steam consumption, the seriousness of this deficiency was evident.

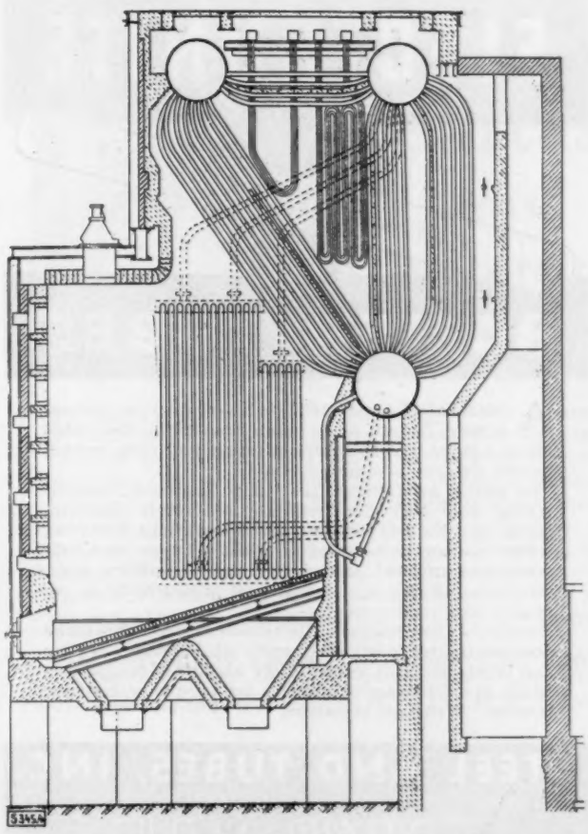
Investigations, cited by the authors showed this to be due to a considerable drop in pressure across the tubes and consequent studies were made with different groupings of the tubes in selected condensers. These are illustrated and the readings indicated.

As a result of this study one of the first steps was to replace the older down-flow arrangement by a central-flow arrangement in which the steam is given access to the whole periphery of the tube nest by providing a volute enclosing the nest and thus eliminating steam lanes. A late step involved radial pitching of the tubes instead of triangular pitching in the outer rows.

Pulverized Fuel Firing for Raw Coal Dust

The combustion of unpulverized coal dust in pulverized fuel installations and its development at the Stinnes plant in Germany, as described in *Warmewirtschaft*, vol. 15, no. 2, is of interest because of the elimination of grinding costs.

The illustration shows a typical furnace bottom which is built of perforated refractory blocks. Next to providing sufficient burner and floor air capacity, the most important matter when burning non-pulverized fuel dust or raw dust is to obtain and maintain a suitable floor temperature. The air through the burner furnishes the required amount for burning the floating dust particles. The air through the floor is necessary for granulating the slag layer on the refractory blocks and for consuming the coal particles which have fallen down. Melting of the slag must be avoided so as not to seal the air ports. The flame must not touch the floor and the temperature above the floor must be kept suitable to the



Section through dust-burning furnace

How to Fire By The DRAFT GAGE

$45 Surface Mounting

$48 Panel Mounting

Ellison Pointer Draft Gage—Dial Type

THIS 2-pointer gage is used for the furnace draft and pit pressure of forced draft stokers not exceeding 4″ pressure under the fire. With midwestern coals, low fusing point and refractory furnace walls, the furnace draft with fuel bed of normal thickness and in good condition should be not less than from .10 to .15″ as shown on the top scale which is graduated plus .1 to minus .5″, a combined range of .6″ over 6″ scale. The pointer movement is multiplied 10 times, the most satisfactory for this type installation. Lower furnace draft for such coals results in rapid burning out of the furnace walls, unless water cooled.

The forced draft, bottom scale, is then reduced to the lowest pressure that will carry the load—usually from 1½ to 2½″. For changes in load the forced draft pressure is changed, not the furnace draft under normal load range.

Next Lesson in November Issue

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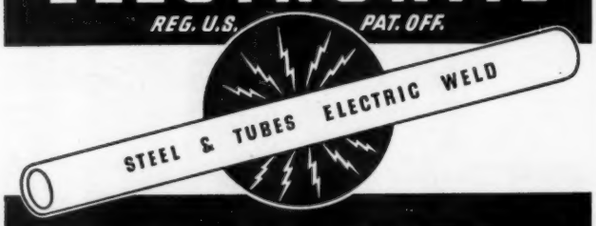

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The weld is as strong as the wall. Diameter, concentricity and wall thickness are absolutely uniform. Inside and outside surfaces are smooth and free from scabs, slivers and rolled-in scale. Tubes are full-normalize-annealed, soft, ductile and of uniform grain structure. Every tube is tested at pressures far in excess of code requirements.

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fusing temperature of the ash by the control of the flow of cool air from beneath the floor. As in all other pulverized fuel firing, the amount of the radiant heating surface is dependent upon the kind of coal. Coal of lean volatile content requires a higher furnace temperature for ignition than that of greater volatile content and the radiant heating surface is arranged accordingly. Trials have shown that slagging over the air ports may be entirely avoided even with difficult coals.

The function of the grate-like floor lies in granulating the slag and in the almost complete consumption of the fuel. The coarser particles, which naturally do not remain in flotation, fall on the glowing floor and are consumed there. The air passes through perforated refractory blocks, simultaneously cools them, furnishes the air for combustion, granulates the ash and moves it sidewards toward the wall, where it then may be removed manually. Efficiencies of from 80 to 82 per cent have been obtained with the use of non-pulverized coal dust. Tests have further shown that for equal heat release within the furnace, the fuel is as well burnt out with non-pulverized coal dust as with pulverized.

The illustration shows a recent installation with a furnace having partially water-cooled walls, which is arranged with the Hold raw-coal firing. The boiler has 692 sq m of heating surface and the furnace volume is 130 cu m. There are 0.188 cu m of furnace volume for each square meter of boiler heating surface. A finned economizer of 854 sq m and a superheater of 275 sq m complete the heating surface. A seven-hour steaming test on non-pulverized gas-coal dust gave the following results:

Fuel	Gas coal H_u = 6732 kcal/kg 25% volatile matter 43.1% remaining on sieve 70 20.9% remaining on sieve 30
Liberation, kcal/m³/hr	196,000
Heating surface load (normal steam), kg/m²	42.22
Normal steaming figure	8.63
Efficiency	82 per cent

The article reviews additional tests, including application of the furnace to flue-type boilers, and states that the question of burning non-pulverized coal dust is solved. Particles up to 3 mm of different volatile coals are well burned with this type of firing in large or small installations. Efficiencies of an average of 80 per cent were obtained. It states further that the simplicity of this mode of firing is marked when compared to pulverized-fuel firing with its preparation plants.

Mine Mouth Power Plants

F. G. Bailey, President of the British Association, in his presidential address delivered at Aberdeen on September 6, and reported in the September 14th issue of *Engineering* again brings up the subject of mine-mouth power stations. With two-thirds of the population within 40 miles of the mines, large quantities of low-grade coal going to waste or being burned inefficiently in colliery power plants, and some of the existing central power stations having outgrown their natural water facilities so as to make their locations no longer a factor, Mr. Bailey sees an economic advantage in mine-mouth

power plants feeding into the present Grid System. He points out that, because of the very much cheaper fuel at the mines less expensive stations of smaller size could be built and thus reduce the fixed charges.

Extensions to British Power Stations

According to the August issue of *World Power*, the Central Electricity Board has announced plans for further extensions to existing British stations involving an expenditure of over 5 million pounds (25 million dollars). This will increase the capacity of the Grid System by over 500,000 kw, and involves fifteen stations with the addition of 39 large boilers and 10 turbine-generators. The decision to carry out these extensions is looked upon as an indication of revival in industrial activity.

Influence of Boiler Scale

E. A. Smith in the September issue of *The Fuel Economist* (London) discusses "The Thermal Influence of Boiler Scale," as affecting the transfer of heat through boiler plates and the consequent effect on fuel consumption. Boiler steel has a thermal conductivity at 212 F of about 2000 Btu per sq ft per hr for a temperature gradient of 1 deg F and across a thickness of $^1/_4$ in. The same area and thickness of an average chalk scale would permit a heat flow of only 300 Btu for the same gradient. This means that with a scaled boiler plate the heat flow on arriving at the plate-scale interface, will bank up, owing to the new thermal resistance and a new temperature gradient will be established.

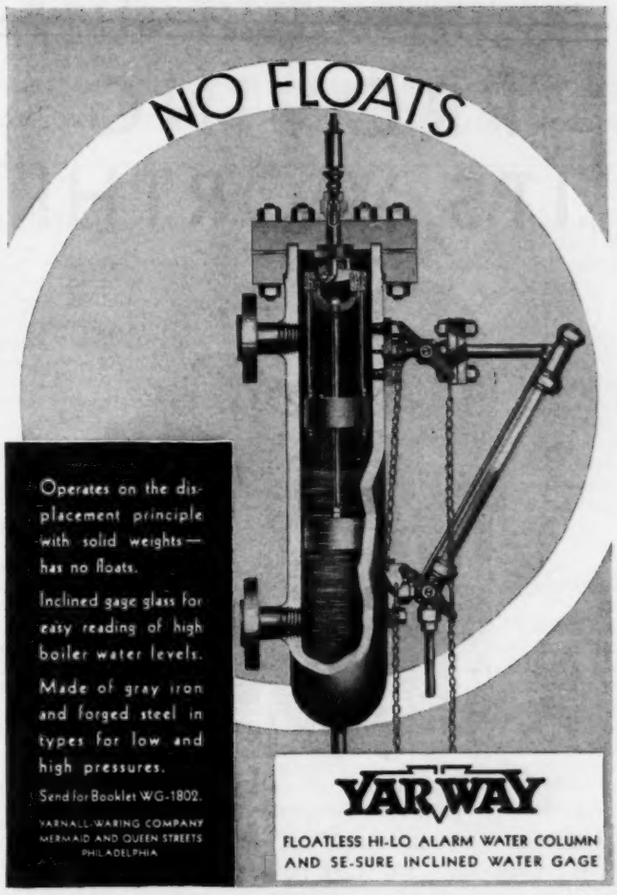
The following figures were obtained on five tubes of the same dimensions but with different thicknesses of scale

Ave. Scale Thickness	Transmission, Btu/hr	Temp. Difference, Deg F
Clean tube	29,854	873
0.02 in.	27,258	877
0.04	26,370	859
0.07	30,678	899
0.13	27,270	855

That the heat flows and temperatures do not bear a simple relation to one another is due to differences in the character of the scale. The composition of the scale has an important influence on the fuel loss, which can vary as much as 50 per cent. A scale containing a high percentage of calcium carbonate will generally offer the least resistance to heat flow, whereas one containing considerable magnesia offers a very high resistance.

Dunstan Station

Under title "British Steam Engineering Progress on the Northeast Coast," *The Steam Engineer* (London) for September, describes in some detail the features of the new Dunstan Station. This is designed for an ultimate capacity of 300,000 kw, half of which is now installed with twelve boilers supplying three 50,000 kw turbine-generators at 700 lb steam pressure and 840 F temperature. Eight of the boilers are fired with traveling grate stokers and four have pulverized coal. Reheat is employed on half the boilers and two have steaming economizers.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Well, the engineer in one large power plant recently installed 112 of the new BAYER Balanced Valve-in-Heads replacing competitive heads.

He was tired of excessive soot cleaner maintenance and wanted a smooth operating valve that would keep **steam tight.**

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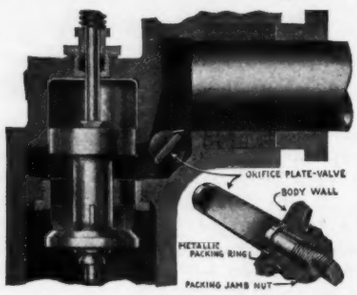

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Effect of Preheat with Underfeed Stokers

The U. S. Bureau of Mines has just issued Bulletin 378, by P. Nicholls, dealing with underfeed combustion, in which the effects of preheated air were studied. The tests were made in a refractory-lined fire-pot and while the results may not agree fully with what occurs in a large stoker, they will help those who operate such stokers to analyze better what actually happens.

The tests show that the additional heat contained in the preheated air is utilized partly in increasing the rates of reaction in the fuel bed and partly in increasing the temperature of the gases leaving the fuel bed. Moreover, with preheat there will usually be more CO in the gases and more secondary air will be required.

Presumably, the higher temperature of the gases leaving the fuel bed will tend to produce better combustion in the combustion space, but as this increase is added to an already high temperature it is questionable whether the benefits gained because of the increased temperature of the gases from the preheat will offset the disadvantage that there is in more CO, and thus more secondary combustion action will be required. Furthermore, the available higher temperature of the top of the fuel bed and in the gases will be lowered because of the increased radiation to the water surfaces. While it would appear from this that preheat gives only limited assistance to combustion, it does not detract from the value of preheat as a means of producing increased over-all economy.

Preheat Permits Higher Ratings by Increasing Rate of Ignition

The tests showed that the outstanding effect of preheat on all fuels was that it increased the rate of ignition, that it permits higher ratings to be obtained, and that a moderate preheat will increase the range of output materially.

Because preheat increases the rate of ignition, if the preheat used produces a rate of ignition greater than that required for the rate of burning, it will tend to bring the burning nearer the metal of the stoker. Consequently, burning of stoker parts with preheat may be due directly, not to the increase in temperature because of the added heat, but because it causes the fuel to burn nearer the metal.

In this investigation it was impossible to make a successful test with preheat of 400 deg, whereas higher temperatures have been used in service. This is no anomaly, because the method of test necessitated heating all the coal and maintaining it at the full temperature for one hour or more. In service the coal will not be heated materially until it meets the air stream.

It is difficult to suggest advantages because of improvements in burning characteristics that will result from the use of preheat at low rates of burning, and improvements from its use must be found in increased rate of combustion for the same air rate and better combustion in the combustion space, as well as increased over-all economy of the unit.

E. J. Kohn has been appointed to succeed the late F. G. Cutler as chief of the Bureau of Steam Engineering at the Tennessee Coal Iron & Railroad Company, Birmingham, Ala.

NEW CATALOGS AND BULLETINS

Any of the following publications will be sent to you upon request. Address your request direct to the manufacturer and mention COMBUSTION Magazine

Belt Conveyor Machinery

A 96-page catalog on belt conveyor machinery for elevating and conveying has just been issued by the Palmer-Bee Company of Detroit. This describes a complete line of conveyor equipment for handling coal in power plants as well as for handling other bulk materials and covers idlers, pulleys, bearings, take-ups, trippers, belting, speed reducers and both single- and double-roll crushers. It forms section No. 103 of the company's general catalog. Engineering data pertaining to application are included.

Conveyor Elevators

Stephens-Adamson Mfg. Co. of Aurora, Ill., has just published a 16-page catalog describing its Redler conveyor-elevator—a new and unique method of conveying bulk materials horizontally, vertically, up inclines and even around curves. The conveyor consists of an enclosed steel trough, through which is pulled a light skeleton conveying element that causes the material to flow in a solid column. The conveyor will feed itself a full load from bins or hoppers and can be discharged at any point by opening slide gates in the casing. The new catalog gives details, sizes, capacities and illustrates the conveyor-elevators handling coal and other bulk material.

Combustion Control

Catalog S-10 on "Smoot Regulators" has just been issued by Smoot Engineering Corporation, now a division of Republic Flow Meters Company, Chicago. The principles of operation are described and illustrated, and include control elements of the single diaphragm type, the compound diaphragm type, high-pressure type, bell-float type, high-pressure differential type, mercury differential type, speed governor type and piston type. The pilot valve and relay cylinder are described in detail as are also Smoot Regulators of the air-operated type. Specifications are included.

Electric Instruments

Catalog GEA-602D has just been issued by the General Electric Company, Schenectady, N. Y., giving information on standard lines of switchboards, portable and laboratory instruments. Dimensions and prices are included as well as descriptive material. The catalog contains 161 pages, fully illustrated.

Gaskets

Flexitallic Gasket Company, Camden N. J. has brought out a new catalog covering its line of gaskets for pipe flanges and all boiler openings, water walls, economizers, superheaters and pressure vessels. The principles of Flexitallic construction are explained and their application to pipe flanges, of the raised face, plain, Van Stone or Cranelap types, to manholes and tube caps are illustrated. Specifications and prices are included. A novel feature of the catalog is its spiral wire binding which facilitates handling.

Improved Lubricator

The Victor Lubricator Company, Chicago, has issued a folder describing its new automatic force-feed lubricator in which a new sight feed provides double visibility-reservoir supply as well as rate of feed. Other improvements include a patented washer retainer, larger filler tube and cadmium plated steel in place of brass.

Pulverizer

A new 32-page catalog has just been issued by Raymond Bros. Impact Pulverizer Company, Chicago (Division of Combustion Engineering Company, Inc.), describing its line of roller mills equipped with air separation, kiln mills for drying and pulverizing, super roller mills for large capacities, midget roller mills for small capacities, roller mills with whizzer separator for a wide range in fineness, special exhaust fans and dust collectors. The catalog is beautifully illustrated and contains both descriptive and engineering information.

Pumps

A line of single-stage volute pumps, Type R, is described in a bulletin recently issued by Worthington Pump and Machinery Corporation, Harrison, N. J. These pumps which are direct-connected to the motor, on a single bedplate, range in size from $1^1/_2$ to $2^1/_2$ in. and are built for pressures up to 250 lb per sq in. A table of dimensions is included.

Refractories

A four-page folder issued by Johns-Manville Company, New York, deals with the use of Sil-O-Cel brick as a combination refractory and insulation for temperatures up to 2000 F. The folder contains information on strength, permeability and conductivity.

A loose leaf section on air-cooled walls has been issued by the Furnace Economy Company for insertion in its general catalog No. 30. This illustrates a number of typical installations in the industrial and central station fields with both stoker and pulverized coal firing, and different furnace arrangements for heat releases up to 15,100 Btu per cubic foot.

Roller Bearings

A new 266-page loose-leaf book has been issued by the Timken Roller Bearing Company, Canton, Ohio, giving information in various types of bearings made by that company. New load ratings have been established, conforming to the fatigue life of the bearings, and an explanation of these ratings is included. Much technical data is given as well as information on the selection of bearings.

Vacuum Pumps

A new high-duty vacuum pump is described in Bulletin 50-B11 issued by Roots-Connersville Blower Corporation, Connersville, Ind. This embodies improvements such as roller bearings, herring bone gears, the elimination of stuffing box attention and a redesigned lubrication system.

Waste Heat Boilers

A line of waste-heat boilers of the muffler type designed to utilize heat of the exhaust gases from Diesels and gas engines is described in a 12-page bulletin issued by Foster-Wheeler Company, New York. The bulletin also describes a line of waste-heat water heaters utilizing exhaust from internal-combustion engines.

Water Columns and Gages

Yarnall-Waring Company, Philadelphia, has published an attractively illustrated catalog, No. WG-1803 covering the improved line of Yarway Floatless Hi-Lo Alarm Water Columns and Yarway Vertical and Sesure-Inclined Water Level Gages for boilers. These water columns and gages are built for working pressures up to 1500 lb per sq in. Complete information covering construction and operating features, prices, dimensions, weights, etc., are given, and typical installations illustrated as well as a list of users. There is also included in the catalog a description of the Yarway Eye-Line Indicator by means of which boiler water levels may be read from the boiler room floor.

Water Softeners

Forty-eight pages of useful information on conditioning are contained in Bulletin No. 689 just brought out by the Cochrane Corporation, Philadelphia. While devoted primarily to hot process softeners, the bulletin discusses cold process lime-soda softening, zeolite softeners, the prevention of oxygen corrosion by deaeration, the use of phosphate and how to feed it and feedwater analyses. There are also included tables giving formulae and molecular and equivalent weights of substances frequently appearing in the chemistry of water softening as well as chemical reactions that are often encountered. The text is fully illustrated with photographs and diagrams and should serve as a handy reference for filing.

NOTICE

Manufacturers are requested to send copies of their new catalog and bulletins for reviews on this page. Address copies of your new literature

to

COMBUSTION

200 Madison Ave., New York

EQUIPMENT SALES

Boiler, Stoker, Pulverized Fuel

As reported by equipment manufacturers of the Department of Commerce, Bureau of the Census

Boiler Sales

Orders for 93 water-tube and h.r.t. boilers were placed in August

	Number	Square Feet
August, 1934	93	365,642
August, 1933	108	363,848
January to August (inclusive, 1934)	617	1,827,338
Same period, 1933	635	1,965,920

NEW ORDERS, BY KIND, PLACED IN AUGUST, 1933–1934

Kind	August, 1933 Number	August, 1933 Square Feet	August, 1934 Number	August, 1934 Square Feet
Stationary:				
Water tube	61	300,713	58	305,266
Horizontal return tubular	47	63,135	35	60,376
	108	363,848	93	365,642

Mechanical Stoker Sales

Orders for 232 stokers, Class, 4* totaling 42,903 hp were placed in August by 60 manufacturers

	Installed under: Fire-tube Boilers No.	Fire-tube Boilers Horsepower	Water-tube Boilers No.	Water-tube Boilers Horsepower
August, 1934	183	24,312	49	18,591
August, 1933	157	18,357	61	23,017
January to August (inclusive, 1934)	790	105,396	334	132,562
Same period, 1933	658	84,583	309	112,657

* Capacity over 300 lb of coal per hr.

Pulverized Fuel Equipment Sales

Orders for 22 pulverizers with a total capacity of 128,070 lb per hr were placed in August

STORAGE SYSTEM

	Pulverizers: Total number	No. for new boilers, furnaces and kilns	No. for existing boilers	Total capacity lb coal per hour for contract	Water-tube Boilers: Number	Total sq ft steam-generating surface	Total lb steam per hour equivalent
August, 1934	..	..	..	.....	..	.....	.....
August, 1933	4	4	..	160,000	2	72,432	1,120,000
January to August (inclusive, 1934)	2	1	1	46,000	..	.....	.....
Same period, 1933	6	4	2	220,000	4	109,432	1,445,000

DIRECT FIRED OR UNIT SYSTEM

	Pulverizers				Water-tube Boilers		
August, 1934	19	14	5	125,670	15	79,088	1,107,800
August, 1933	11	10	1	58,500	9	50,164	460,000
January to August (inclusive, 1934)	65	48	17	437,780	50	348,663	3,753,700
Same period, 1933	54	42	12	311,340	44	294,570	2,772,960
					Fire-tube Boilers		
August, 1934	3	2	1	2,400	3	616	23,000
August, 1933	3	2	1	5,500	3	5,710	50,540
January to August (inclusive, 1934)	7	2	5	7,200	8	8,116	64,000
Same period, 1933	12	3	9	13,200	13	19,860	115,440

World Wide Business Conference by Radio and Telephone

Present development in the art of communication as applied to business was strikingly exemplified by a telephone conference between London, New York, Paris, Bombay, Johannesburg, South Africa and Sydney, Australia, on September 25th, when a general conference was held between International Combustion Limited of London, its branches in British possessions, Combustion Engineering Company, Inc. of New York, and its Paris associates.

The conference was opened by George C. Usher, Managing Director of the London company, who reported unusual activity among British power stations. His sales of boilers, stokers and pulverized coal equipment are 120 per cent over the previous year, amounting to more than one million pounds sterling for July and August, with export business showing a gratifying increase. Johannesburg reported increased activity, especially among the power plants of the mines in South Africa. Similar optimism marked the reports from Sydney and Bombay.

The conference was handled by the British Post Office Department, which operates British communication facilities, in cooperation with the American Telephone & Telegraph Company. Both radio and telephone were used.

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